MISSIONE 4
ISTRUZIONE
RICERCA

CERENKOV TELESCOPE ARRAY PLUS (CTA+)

COMPONENTE 2, INVESTIMENTO 3.1, IR0000012,
CUP: C53C22000430006

CAPITOLATO TECNICO

RELATIVO ALL’AFFIDAMENTO, NELL’AMBITO DEL PROGETTO DAL TITOLO "CHERENKOV TELESCOPE ARRAY PLUS (CTA+), DELLA FORNITURA DI DUE STRUTTURE ELETTROMECCANICHE PER I TELESCOPI LARGE SIZED (LST) DEL SITO SUD DI CTA”

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
INAF ISTITUTO NAZIONALE DI ASTROFISICA

MISSIONE 4
ISTRUZIONE
RICERCA

IL PRESENTE **CAPITOLATO TECNICO** INCLUDE I SEGUENTI DUE DOCUMENTI:

- LSTS-SOW-INAF-0001-02 “MOUNT STATEMENT OF WORK”
- LSTS-SPE-INAF-0001-01 “MOUNT TECHNICAL REQUIREMENTS”

I QUALI VENGONO ALLEGATI QUI DI SEGUITO.

THIS “**CAPITOLATO TECNICO**” INCLUDES THE FOLLOWING TWO DOCUMENTS:

- LSTS-SOW-INAF-0001-02 “MOUNT STATEMENT OF WORK”
- LSTS-SPE-INAF-0001-01 “MOUNT TECHNICAL REQUIREMENTS”

WHICH THEY ARE ATTACHED HERE AFTER.

PROCEDURA DI ESTRAZIONE PER GLI ALLEGATI AL CAPITOLATO TECNICO (ARCHIVI COMPRESSI):

1. ESTRARRE CIASCUNO DEI FILE ".ZIP" (ES. "...001.ZIP", "...002.ZIP", "...00N.ZIP" ETC.)

2. PORRE TUTTI I FILE ESTRATTI (CON ESTENSIONE “.001”, “.002” E COSÌ VIA) IN UNA SINGOLA CARTELLA

3. APRIRE CON UNA APP TIPO "7-ZIP", "WINRAR" O SIMILARI, SOLO I FILE CON ESTENSIONE ".001" (ESSENDO SICURI DI AVERE TUTTI GLI ALTRI FILE “.002”, “.003” ECC. NELLA STESSA CARTELLA COME DESCRITTO AL PUNTO 2.)

4. ESTRARRE/COPIARE IL CONTENUTO APERTO NEL FILE ".001" IN UNA CARTELLA DEDICATA

PROCEDURE TO EXTRACT THE ATTACHMENTS OF THE ”CAPITOLATO TECNICO” (COMPRESSED ARCHIVES):

1. UNZIP EACH ONE OF THE ZIP FILES (E.G. "...001.ZIP", "...002.ZIP", "...00N.ZIP" ETC.)

2. PUT ALL UNZIPPED FILES (WITH EXTENSION “.001”, “.002” ETC.) INTO A SINGLE FOLDER

3. OPEN FIRST FRACTIONED COMPRESSED FILE ".001" WITH APP SUCH AS "7-ZIP", "WINRAR" OR SIMILAR (BEING SURE TO HAVE ALL OTHER FILES “.002”, “.003” ETC. IN THE SAME FOLDER AS DESCRIBED IN 2.)

4. EXTRACT/COPY THE CONTENT OF THE OPENED ".001" FILE IN A DEDICATED FOLDER

CTA+
LARGE SIZED TELESCOPE SOUTH

LSTS-SOW-INAF-0001-02
MOUNT STATEMENT OF WORK

	Name	Role (Institute/ Company)	Date	Signature
Prepared by	Andrea Busatta	PM & SE (INAF)	15.03.2024	
Verified by	Massimiliano Mattioli	Management (INAF)	15.03.2024	
Approved by	Angelo Antonelli	PI (INAF)	15.03.2024	

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CHANGE RECORD

Issue	Date	Sections Affected	Modifications	Author
01	20.11.2023	All	First issue	Andrea Busatta
02	15.03.2023	1.3.1 2.1 3.1.1.1 3.1.1.7 3.1.1.8 4.1.2.3 4.1.2.4 4.1.2 4.2 4.3.3 4.3.4 4.3.5 4.3.6 4.4 4.4.2 4.4.5 4.4.6 4.4.7 4.4.8 4.4.9 4.4.10 4.4.11	Options changed. Key personnel approval by INAF added. Foundations reduced to design only. Spare parts reduced to active items. Rephrasing of section content. Factory integration concept introduced. Factory integration concept introduced. Phases scope description changed. Work logic changed with scope. Packing excluded from this phase. Site infrastructure preparation details added. Factory integration and test details added. Dismounting and packing details added. Chapter re-phrased Foundation preliminary drawings added. Procurement reviews updated. Availability reviews updated. Factory Integration Readiness Review details added. Site Readiness Review added. Factory Acceptance Review added. Shipping Readiness Review added. Milestone summary table updated.	Andrea Busatta

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TABLE OF CONTENT

1 INTRODUCTION

1.1 SCOPE OF THE DOCUMENT

This Statement of Work (SoW) intends to address the deliverables, the organizational structure and relative activities requested by INAF (referred alternatively as “Institute”) necessary for the successful completion of the work. The company in charge for the execution of the work (referred to as “Contractor”) will be selected by INAF by means of a tender. Consequently, this SoW must be considered as an applicable document during the entire work execution. In particular it will focus on the following topics:

- Introduction and objectives.
- Organization and monitoring process.
- Deliverables (HW, SW, Documentation).
- Work to be performed (phases, activities, options, milestones and finally schedule).
- Responsibilities and Customer’s right.
- Document Requirements Definition.

1.2 BACKGROUND

The Cherenkov Telescope Array Observatory is an international user facility distributed over four primary sites: Headquarters (Bologna, Italy), Science Data Management Centre (Zeuthen, Germany) and two array sites located in the northern (Observatorio del Roque de los Muchachos (ORM), La Palma, Spain) and southern hemispheres (between Cerro Paranal and Cerro Armazones ESO observatories in Chile).

The Cherenkov Telescope Arrays consists in many tens of telescopes for Gamma Ray observation, divided in three configurations, in order to cover the energy range from a tens of GeV (Large Sizedd Telescope, LST), to a tens of TeV (Medium Sized Telescope, MST), and up to 100 TeV (Small Sized Telescope, SST).

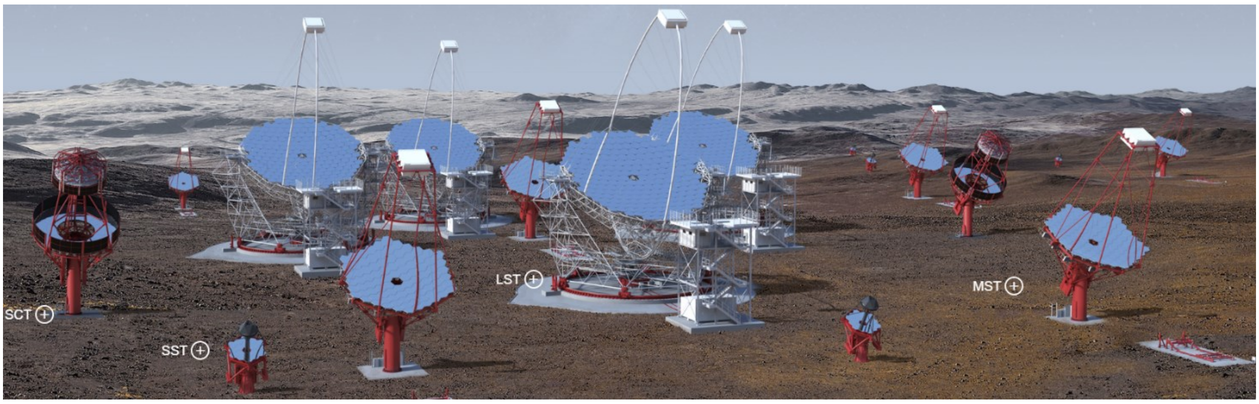

Figure 1.1 Cherenkov Telescope Array artist’s impression

Within this framework, INAF is in charge to design, fabricate and test the Large Sized Telescopes located in the southern hemisphere.

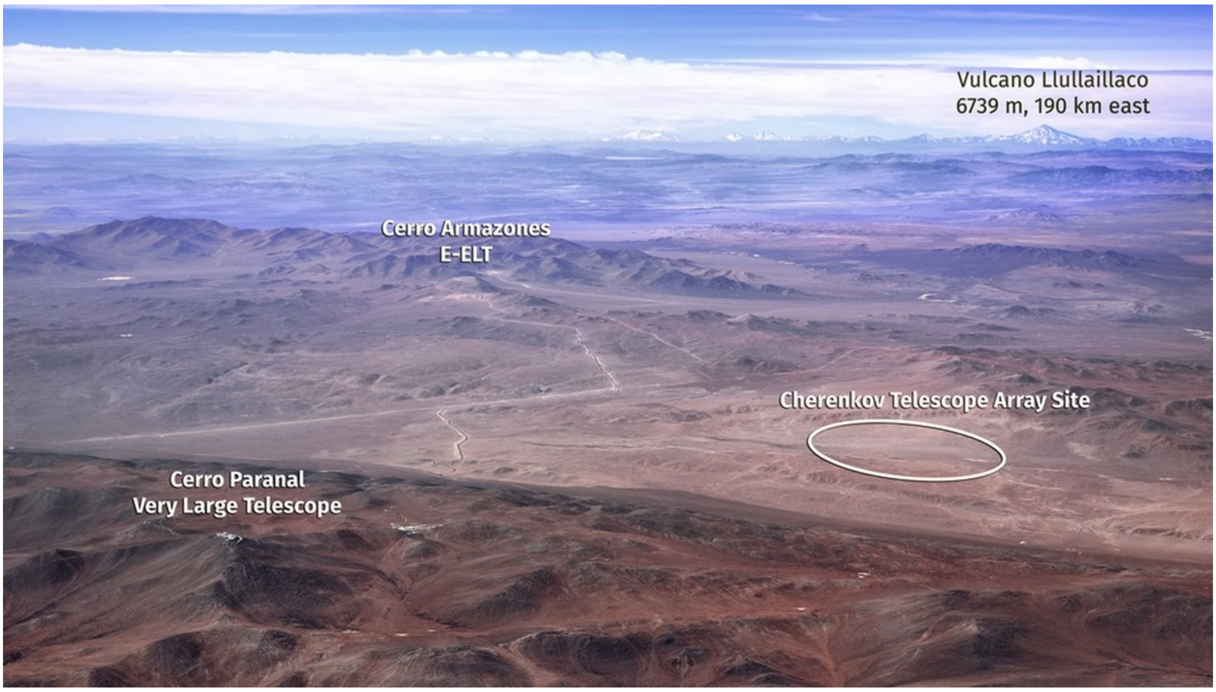

Figure 1.2 CTA South (Chile) location aerial view

The LST is an alt-azimuth telescope which have in a primary mirror of 23 m diameter and 28 m focal length; a larger mirror and higher photo detection efficiency allow to detect low energy atmospheric showers. These types of telescopes normally are arranged at the centre of the array to lower the energy threshold and to improve the sensitivity of CTA between 20 and 200 GeV.

Figure 1.3 Artist's impression of Large Sized Telescope into Cherenkov Telescope Array

1.3 THE PNRR NATIONAL PLAN

The National Recovery and Resilience Plan ("Piano Nazionale di Ripresa e Resilienza", PNRR) is part of the Next Generation EU (NGEU) program that the European Union negotiated in response to the pandemic crisis. The total amount of funds envisaged by Italy amounts to several hundreds of billions of euros implemented on specific axes and strategic missions. It is an intervention that aims at repairing the economic and social damage caused by the pandemic crisis, contributing to addressing the structural weaknesses of the Italian economy, and leading the country along a path of ecological and environmental transition and technological advancement.

CTA+ is a program approved by the Italian Ministry to be funded within the PNRR plan. This tender's objective delivers one important task of the project: the telescope mount for the LSTs in the South (CTA+ WP1220).

To reach the program goal, this tender enforces a specific timeline for the execution of the project whose schedule is one of the most demanding achievements since its end is fixed for June 2025. Moreover, a strict monitoring of the activities, costs and deliverables will be executed during the whole project by a supervisory body in order to ensure that the development of the project, in terms of time and costs, is in line with the proposal approved by the Ministry.

1.3.1 Objectives of the work

The purpose of this work is to build the Large Sized Telescope Mount for the southern site, as described in the next sections, as well as the provision of all the components, system and/or subsystems, for a second one. The activities include a review of the specifications, a design phase, the HW and SW production and, as option:

- Option A: the factory integration and test (as described in detail in 4.3.4), dismounting for the first telescope Mount, and packing of both telescope Mounts, ready for delivery to site (as described in detail in 4.3.5).

1.3.2 Disclaimer

LST-South is funded by European Union – "NextGenerationEU". The points of view and the opinions are only those of the authors and do not necessarily reflect those of European Union or European Commission. Neither European Union nor European Commission can be held liable for those.

1.4 RELATED DOCUMENTS

1.4.1 Applicable documents

AD	Document code	Description
AD01	LSTS-SPE-INAF-0001	Mount technical requirements
AD02	LSTS-SPE-INAF-0003	Azimuth track manufacturing specifications
AD03	LSTS-MDL-INAF-0002	Azimuth central pin manufacturing specifications
AD04	LSTS-SPE-INAF-0004	Azimuth bogies manufacturing specifications
AD05	LSTS-MDL-INAF-0003	Elevation drives conceptual model

AD	Document code	Description
AD06	LSTS-ICD-INAF-0001	Optics to Mount interface control document
AD07	CTA-SPE-TEL-000000-0004_1a	Structural Analysis Guidelines

1.4.2 Reference documents

RD	Document code	Description
RD01	LSTS-TRE-INAF-0001	Telescope conceptual design

1.5 ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Full description
AIT	Assembly Integration Test
AIV	Assembly Integration Verification
AVL	AVaiLability of items (for telescope mount integration)
BOM	Bill Of Material
CFD	Computational Fluid Dynamics
CI	Configuration Item
CIDL	Configuration Item Data List
CRE	Change REquest
CTA	Cherenkov Telescope Array
CTAO	Cherenkov Telescope Array Observatory
COTS	Commercial Off The Shelves
E2E	End to End
FAR	Factory Acceptance Review
FDR	Final Design Review
FEA	Finite Element Analysis
FEM	Finite Element Model
FMECA	Failure Mode Effects and Criticality Analysis
HW	HardWare
INAF	Istituto Nazionale di AstroFisica
ICD	Interface Control Document
IRR	Integration Readiness Review
LRU	Line Replaceable Unit
LST	Large Sized Telescope
KOM	Kick Off Meeting
MIP	Manufacturing Inspection Point
MRR	Manufacturing Readiness Review
MST	Medium Size Telescope
OEM	Original Equipment Manufacturer
PA	Product Assurance
PBS	Product Breakdown Structure
PDR	Preliminary Design Review

Acronym/Abbreviation	Full description
PI	Principal Investigator
P&I	Piping and Instrumentation
PM	Project Manager
PO	Project Office
PRC	PRoCurement of items (for telescope mount integration)
TRR	Test Readiness Review
RAM	Reliability, Availability and Maintainability
RAMS	Reliability, Availability, Maintainability and Safety
RFD	Request For Deviation
RFW	Request For Waiver
RIX	Review Item X=Discrepancy (RID), Comment (RIC), Question (RIQ)
SE	System Engineer
SoW	Statement of Work
SST	Small Size Telescope
SW	SoftWare
TRR	Test Readiness Review
WBS	Work Breakdown Structure
WDR	Workshop Design Review
WP	Work Package
WPD	Work Package Description

2 OVERALL ORGANIZATION AND MONITORING

The followings are the requirements for Management, Reporting, Meetings and Deliverables applicable to the present activity.

2.1 PROJECT ORGANIZATION

The sections below describe, on one hand the Institute's organization responsible for the project and on the other the requirements for the Contractor's organization. The former is the LST South Project Office, it is responsible for the whole project as well as the development of the present work and it represents the interface with the Tenderer. The latter represents the minimum requirements for the Tenderer's organization which is expected to be proposed and put in place. All key personnel proposed by the Contractor, need to be approved by INAF PO.

2.2 INAF ORGANOGRAM

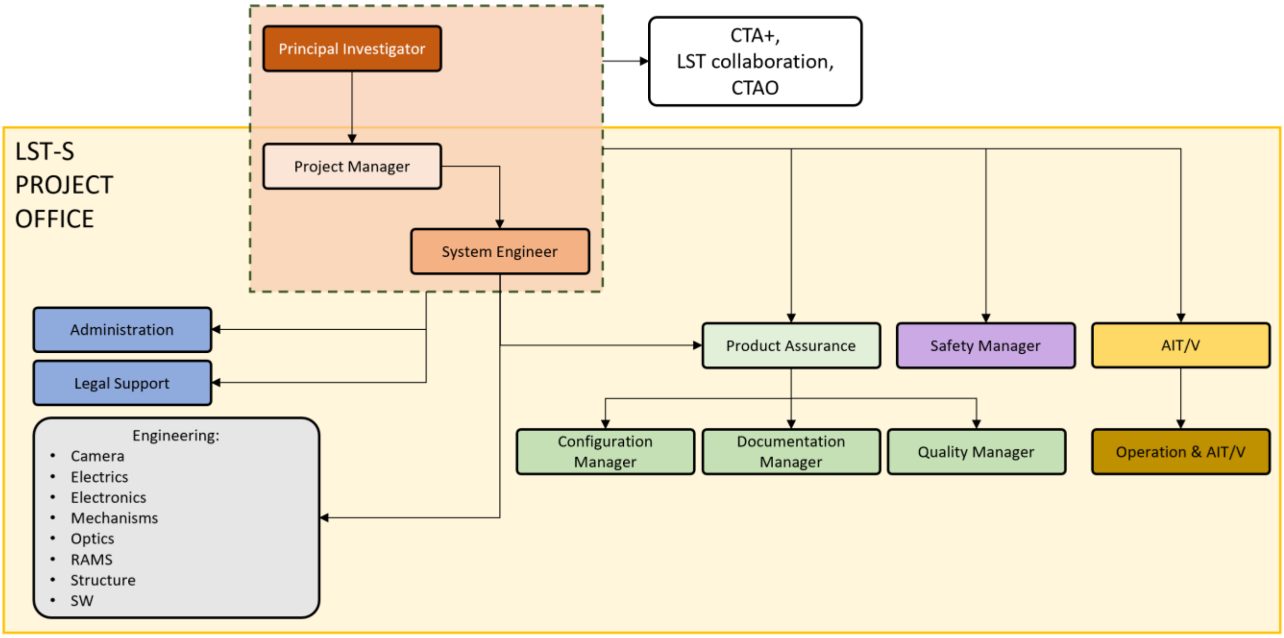

Figure 2.1 INAF Organogram

2.3 KEY CONTRACTOR PERSONNEL

The Contractor shall be responsible to explicitly identify the project organization and at least the followings:

a) Project Manager: the Contractor shall assign an experienced professional Project Manager to manage the Work throughout all Phases of the Work. The Project Manager shall have sufficient authority to control the Work to meet technical, cost, and schedule requirements. The Project Manager shall be the principal point of contact with INAF for all managerial and contractual matters.

b) System Engineer: the Contractor shall identify a professional engineer with extensive experience in the design of highly complex systems. The System Engineer will be responsible for overseeing the development of the technical design, relative technical documentation and its up-to-date configuration and will ensure compliance with the technical requirements and interfaces. The System Engineer shall be the principal point of contact with INAF for all technical matters.

c) Contract Manager: the Contractor shall identify a Contract Manager who works as Authority to make contract changes, approve change orders and amendments in agreement with Project management.

d) Safety Manager: the Contractor shall appoint a Safety Manager for the responsibility of the Contractor's Safety Plan, and for overseeing all safety aspects of the LST-S. The Safety Manager shall be the principal point of contact with INAF for all safety matters.

e) Product Assurance Manager: the Contractor shall identify a Product Assurance Manager who has the responsibility for the Contractor's Product Assurance Plan, and for overseeing all product assurance aspects for configuration, quality, and documents of the LST-S during its production, assembly and verification activities. In particular, he/she will work with System Engineer to assure adequate requirements traceability and compliance.

f) AIT Manager: the Contractor shall assign an AIT Manager in charge of developing the activities and the documentation relative to Assembly Inspection and Test activities.

g) Engineering disciplines key personnel: the Contractor shall provide the key personnel in charge for LST-S:
   - Structure,
   - Mechanisms,
   - Electrical systems,
   - Plant systems,
   - Motion control systems,
   - SW,
   - RAMS.

2.4 MEETINGS AND REVIEWS

The Contractor shall perform the following reporting and reviews throughout the duration of this effort. Each review requires delivery of both a written report and an actual presentation (in English).

2.4.1 Weekly meetings

The Contractor shall provide progress updates to INAF PO at least weekly remotely. Formal presentations of overall program status are not required, but the Contractor shall be prepared to discuss schedule status, technical issues, critical risks and resolutions, and manpower. The objective of these updates is to keep the INAF PO informed of progress and problems and to enable interactive efforts toward arriving at effective engineering designs and issue resolutions.

In summary:

- Normally held remotely.
- The Contractor shall send the agenda 2 days in advance.

- The Contractor shall produce presentations if deemed necessary.
- The Contractor shall manage, discuss, collect, and share the action Item status.
- Minute shall be agreed and signed at the end of the meeting.

2.4.2 Monthly meetings

During the development of the entire work, the Contractor shall support formal progress updates which shall take place normally at Contractor's premises unless INAF PO decides differently. Especially during the production phase, these meetings shall be held where the parts are in fabrication to allow direct inspection, so the Contractor shall grant proper access to production facilities.

In summary:

- Normally held at Contractor's facilities every month (unless otherwise requested by INAF PO).
- The Contractor shall send Agenda 5 working days in advance.
- The Contractor shall produce Presentations if deemed necessary and present the content of the Monthly Progress Report.
- The Contractor shall manage, discuss, collect, and share the action Item status.
- Minute shall be agreed and signed at the end of meeting.

2.4.3 Review process

The Contractor shall host specific meetings and reviews throughout the duration of this effort as described below and identified by the Contractor in their Project Plan. These meetings shall provide the INAF PO the ability to review and approve Contractor plans and results to ensure work compliance and to enable payment. Where necessary, the INAF PO will provide written approval of the completion of activities for payment.

Specific requirements for Milestone completion, payment application, and purchaser review are provided in the contract document. The Contractor is encouraged to integrate multiple topics (where plausible) to minimize the number of in-person meetings.

In summary:

- All Review dates shall be decided at KOM (possible date changes will be discussed at each Review).
- Minute shall be agreed and signed at the end of the meeting.
- Review process:
  - The Contractor shall send the review documents 2 weeks in advance with respect to the meeting date.
  - INAF PO will send RIXs 1 week in advance with respect to the meeting date.
  - The Contractor shall send the agenda 1 day after receiving the RIXs.
  - The Contractor shall send presentations to address agenda topics 1 day in advance with respect to review meeting dates.
  - Conduct the review meeting as agreed at KOM (with minute signed at the end).

- After review meeting, all open points shall be closed by the Contractor within 2 weeks, unless otherwise specified and mutually agreed.
- INAF PO will send the milestone closure through an official note.
- Payment will occur according to contract.

2.5 CHANGES

Both INAF and the Contractor may start a change request affecting the SoW, Technical specifications, Interfaces, etc. In this case, the Contractor shall deliver to INAF a proposal including schedule, cost and adequate justification for any change initiated by INAF PO or by the Contractor. The work shall not commence prior to reach a full mutual agreement of the change by the Parties, followed by a written authorization note sent by INAF PO signed by both parties.

The Contractor may involve any third party for the change implementation if deemed necessary; INAF reserves the right to involve any third party for the analysis of the proposal from the Contractor in case that is not fully satisfactory, and a negotiation agreement is not reached.

3 THE LARGE SIZED TELESCOPE AT THE SOUTH DELIVERABLES

3.1 PRODUCT BREAKDOWN STRUCTURE

Here it is reported a table with the product tree or product breakdown structure of the entire LST-S Telescope. Parts with grey background are not intended to be part of the scope outlined within this document.

PBS	Level 1	PBS	Level 2	PBS	Level 3
1	Mount Structure				
		11	Foundations		
		12	AZ structure		
				121	AZ base
				122	AZ fork tower +X
				123	AZ fork tower -X
		13	AZ bearing		
				141	AZ rail
				142	AZ central pin
		14	AZ Access		
		15	EL structure		
				151	Back structure
				152	Dish
				153	Camera support structure
		16	EL bearing		
		17	EL access		
2	Axes Motion				
		21	AZ motors		
		22	AZ encoder		
		23	AZ switches		
		24	AZ brakes		
		25	EL motors		
		26	EL encoder		
		27	EL switches		
		28	EL brakes		
3	Ancillaries				
		31	AZ cable wraps		
		32	AZ manual drive		
		33	AZ lock		
		34	EL cable wraps		
		35	EL manual drive		
		36	EL lock		
		37	Pointing Calibration Systems (PCS)		
		38	Instruments maintenance		

PBS	Level 1	PBS	Level 2	PBS	Level 3
				381	Mirrors maintenance
				382	Camera maintenance
		39	Mount SW		
4	Fluid plants				
		41	Cooling		
5	Electrical plant				
		51	Cabinets		
				511	Main Interface Cabinet
				512	Power container
				513	Drive container
				514	Camera cabinet
				515	AMC main cabinet
				516	PCS main cabinet
		52	Cable routing	511	Main Interface Cabinet
		53	Lightning Protection System (LPS)		
		54	Energy Storage System (ESS)		
6	Telescope Control System				
7	Optics				
		71	Primary mirror		
		72	Actuators		
		73	Actuators Support		
8	Camera				
9	Infrastructure				

3.1.1 HW & SW Description

3.1.1.1 Mount structure

Mount structure is the structure which basically has the aim to support the mirrors, camera and allows them to be pointed towards the targets with sufficient stability under environmental loads. Foundation is included as it is deemed as part of the overall stiffness of the mount structure. The elevation over azimuth structure and the bearings which connect the structure moving parts are included entirely in the scope of this work as well as the access means. Moreover, maintenance and handling devices for dismounting and handling of Mirrors and Camera (namely Camera maintenance platform) are also included.

Consequently, the Contractor shall deliver (including design, procurement, integration, and test) with the following exceptions/notes:

- The Contractor shall design the foundation for South site. Just for information, the site availability will be provided by a third party (CTAO) during the execution of the work. The construction of the foundation is **not** part of the scope of this work.
- The Contractor shall build the AZ rail system with the documents provided in AD02. This design is used in LST-N thus, it shall be intended as interchangeable. Any sensible design change shall be justified by documented functionality or performance issues.
- The Contractor shall build the AZ central pin with the documents provided in AD03. This design is used in LST-N and consequently it shall be intended as interchangeable. Any sensible design change shall be justified by documented functionality or performance issues.
- The Contractor shall build all provisions and device for Mirrors and Camera maintenance and handling with exception for those concrete platforms which may be part of the site foundations.

3.1.1.2 Drives

All hardware included in this section are part of the scope of this work and they are relative to all the systems that move safely (for people and HW) the telescope mount structure with the performance imposed by the Technical Requirements (see AD01).

In particular:

- Motors are intended as the entire units (mechanical parts included) that provide the motion of the telescope main axes under all conditions foreseen. For the AZ bogies, the Contractor shall assess and optimize the design aspects relative to RAM (e.g. through FMECA, fatigue analysis, fault tree, maintenance strategy, failure detection etc.) included in the documents provided in AD04. Any change shall be discussed and approved by INAF PO, provided that, the Contractor shall limit and justify it by RAM implications in order to preserve the overall design concept. For the EL drives, the Contractor shall use the design concept included in the documents provided in AD05. Any change, must be demonstrated, justified by major issues.
- Encoders are the units necessary to provide feedback for the position loop closure.
- Switches are the units that guarantee to move the telescope and the telescope parts within the allowed functional and safety boundaries with adequate redundancy.
- Brakes are the units intended to stop the telescope in case of emergency.

Handling and maintenance devices need to be considered as included in the scope of this work. Condition monitoring sensors shall be included in the scope of this work if a RAMS analysis demonstrates they will be essential to avoid major failure and consequent problems of availability. Nevertheless, main axes motors condition monitoring sensors shall be considered necessary.

3.1.1.3 Ancillaries

All these units are necessary to make the telescope mount work in all conditions. Those are all part of this work unless not specified otherwise.

In particular:

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- Cable wraps are the units which allow the correct utilities ways (e.g. cables and pipes) between two parts which moves relative to each other.
- Manual drives are the part of the system that allow to move the telescope in emergency conditions (e.g. power failure).
- Locks are the units which park the telescope safely when not in use. They shall be capable to withstand survival events.
- Pointing and Calibration systems are those units that retrieve telescope pointing coordinates, Camera position and provide feedback for the necessary compensations. These units are **not** part of the scope of this work; nevertheless, interfaces must be present as per the dedicated ICD included in AD01.
- Maintenance section refers to additional maintenance and handling devices necessary for those products that are **not** part of the scope of this work. In this last case:
    - Mirrors (for which there will be a dedicated ICD – included in AD01)
    - Camera (for which there will be a dedicated ICD – included in AD01), although a dummy needs to be produced by Contractor.

Handling and maintenance devices for these units need to be considered included in the scope of this work. Condition monitoring sensors shall be included in the scope of this work if a RAMS analysis demonstrates they will be essential to avoid major failure and consequent problems of availability. Nevertheless, main axes lock devices condition monitoring sensors shall be considered necessary.

3.1.1.4 Fluid Plants

The fluid plants and fluid production units necessary for the functioning of the telescope and all its sub-units included in the scope of this work, are to be considered part of the scope of this work. For example, the chiller for production of coolant necessary for camera are **not** part of the scope of this work. Exceptions will be outlined within ICDs applicable to AD01 (e.g. pipes and cables along the structure for the Camera).

Condition monitoring sensors for the machines included in the fluid circuits systems shall be included in the scope of this work if an analysis demonstrates they will be essential to avoid major failure and consequent problems of availability. Nevertheless, fluid circuits condition monitoring sensors (temperature, pressure etc.) shall be considered necessary.

3.1.1.5 Electrical Plant

The electrical plant is part of the scope of this work. It includes all the items, cabinets, containers and provisions to power and control the telescope as well as provide the adequate and safe electrical supply and protection to all units (EMC compatible and without interference effects). The electrical infrastructure interfaces (power and data for which there will be an infrastructure ICD – included in AD01) shall be respected to make the telescope part of the array.

The Energy Storage System (ESS) is **not** part of the scope of this work but it must be taken into account during the design and test activities (for which there will be a dedicated ICD – included in

AD01) as this system will be a sub-product of the telescope. If required, Contractor shall procure temporarily the ESS (or equivalent) for test purposes.

Condition monitoring sensors shall be included in the scope of this work if the RAM analysis will demonstrate they will be essential to grant enough reliability/availability of the telescope mount.

3.1.1.6 Mount LCS software

The telescope active systems that are monitored and/or commanded locally or remotely, need to be part of a SW environment which allow the full functionality and performance of the telescope. This SW shall interface properly with higher level SW (for which there will be a dedicated ICD – included in AD01).

During the development of the Mount LCS SW the Contractor shall deliver the Control SW and a controller simulator software to INAF to enable testing of the interfaces as their definition mature over time.

The Contractor shall deliver all software in source format and shall include the manuals to provide the documentation needed to support operation of the control system.

3.1.1.7 Spare parts and consumables

The Contractor shall deliver sufficient spares of critical elements highlighted by RAM analysis (e.g. long lead items and/or with “difficult” market availability) to ensure continuous operation over the 10 years at the specific duty cycle. All spares shall be complete with all software and electronics. All equipment and data needed for calibration of the spares shall be provided including software and scripts.

The Contractor shall identify all items which require scheduled servicing and supply all recommended servicing and maintenance procedures to maintain and prolong operation. Servicing instructions shall include inspections of such equipment to evaluate conditions on a periodic basis. A list of all components that are not expected to meet the 30-year design lifetime shall be provided along with their predicted lifetime.

At least one spare shall be provided for all major critical active components that could fail during telescope lifetime. At minimum this requires that one of each of the followings shall be provided:

- AZ and EL motors and drive.
- AZ and EL encoder.
- AZ and EL brake.
- Switches.
- AZ and EL lock actuators.

3.1.1.8 Customer provided HW

It is necessary to explicitly mention that INAF will be responsible for the following HW, so they are **not** part of this work:

- Mirrors, actuators, fixed points and their distribution boxes.

- Cherenkov Camera and its ancillary systems on board of the telescope.
- Pointing & Calibration Systems.
- Energy Storage System.

This does **not** mean that if tests need to be carried out, those piece of HW will be provided by INAF. Contractor shall consider that everything requires to be verified autonomously with dedicated temporary means (dummies, electric generator to supply surplus of power etc.) unless differently agreed with INAF PO.

3.2 DOCUMENTS

This section describes types, versioning, and coding logic to be adopted for the whole project repository. The complete set of documentation required is reported in section 6.

3.2.1 Document type

The Contractor shall produce all the documents in order to accomplish milestone requests outlined in the dedicated milestone summary table (see section 4.4.10).

Documents need to be classified in different type in function of their use. The following table gives the principle to address each document content:

Type	Acronym	Description
BOM	Bill Of Material	See section 6.5.4.
CRE	Change REquest	This type of document is necessary to keep traceability of all requests of change for the project. See 6.4.6.
DWG	Drawing	See section 6.5.3.
ICD	Interface Control Document	See section 6.2.2.
LIS	LISt	This type of document must be used when items, activities or deliveries must be put in list form (exception is foreseen for Bill Of Material). For example, drawing list, documentation status list or configuration item data list, cost work or product breakdown, compliance matrix, action item list etc.
MAN	MANual	This type of document outlines the way an item, an assembly or the entire telescope should be used and/or maintained.
MDL	MoDeL	This type of document is referring to all models used to demonstrate compliance to specifications such as (but not limited to): • 3D CAD (native and neutral) • Finite Element Models (FEM) • Mathematical models (eg Simulink, MatLAB etc.) In case models include more files, they can be collected in compressed format with, in addition, a text file (.txt) which list the entire content.

Type	Acronym	Description
MOM	Minute Of the Meeting	See section 6.3.2.
MPR	Monthly Progress Report	See section 6.3.3.
PLA	PLAn	See chapter 6 to refer to all documents which provide planning of the work, including schedule.
PRO	PROcedure	Documents to provide step by step procedures for: • assembly/disassembly • maintenance • inspection • tests
TRE	Technical REport	Document which reports: • Design descriptions, • Model descriptions, analyses and relative results. • Inspection results • Test results They are the instrument to demonstrate the requirements compliance.
NTE	NoTE	A short document reporting a topic of managerial or technical nature. Normally are used for official communications.
NCR	Non-Conformance Report	This type of document is necessary to keep traceability of all non-conformances for the project. See section 6.4.3.
RFD	Request For Deviation	This type of document is necessary to keep traceability of all requests for deviation for the project. See 6.4.4.
RFW	Request For Waiver	This type of document is necessary to keep traceability of all requests for waiver for the project. See 6.4.5.
SLI	SLIdes	Presentation including any type of technical and/or managerial info
SPE	SPEcification	Document which specifies the technical requirements to be satisfied by the work.
SOW	Statement Of Work	Document stating the scope of a work.

MOM, RFD, RFW, CRE, NTE, NCR shall have dedicated lighter template (see dedicated document description section) in order to be documents with only the pages necessary for the content light and easy to be read.

The Contractor will produce all template and format will be approved by INAF PO at Kick Off Meeting.

Written documents (not models, like CAD, FEM, Servo etc.) shall be produced in English and, unless otherwise specified, shall be provided always in pdf format.

Models (and drawings in general) shall be provided in native format and complete as they are needed to run and/or upgrade the telescope for its full lifetime.

3.2.2 Revisions and drafts

Draft versions of documents will necessarily have the suffix to revision with “D” and a sequential number with two digits.

3.2.3 Documents coding

For all documents except drawings and bill of materials, the code will have the following coding (draft versions will have the extension included between brackets):

LSTS-TTT-XXXX-0000-RR(D00)

- LSTS → Large Sized Telescope at South site.
- TTT → Type of documents as per table above.
- XXXX → Organization.
- 0000 → Sequential four-digit number (every document type from each organization will start from 0001).
- RR → double digit number to identify the revision, extended of “D00” when in draft version.

For all the drawings or bill of materials the code will have the following coding (draft versions will have the extension included between brackets):

LSTS-DWG-XXXX-000000000-RR(D00)

- LSTS → Large Sized Telescope at South site.
- DWG or BOM → Drawing or Bill Of Materials.
- XXXX →Organization
- 000000000 → Configuration item number made of 9 numbers (taking into account 7 assembly levels and 2 last digits for items included in the assembly).

RR → double digit to identify the revision, extended of “D00” when in draft version.

3.2.4 Disclaimer for documents

Each document produced within the effort described within this SoW shall include the following disclaimer: “LST-South is funded by European Union – “NextGenerationEU”. The points of view and the opinions are only those of the authors and do not necessarily reflect those of European Union or European Commission. Neither European Union nor European Commission can be held liable for those.”

4 WORK TO BE PERFORMED

4.1 WORK BREAKDOWN STRUCTURE

The work package WP1220 to be carried out for the realization of the telescope mount shall be divided as follows:

- LST-South Subsystem Management (WP 1220-1)
- LST-South Subsystem Procurement (WP 1220-2)

This must be used as it is a directive imposed by PNRR submitted proposal.

4.1.1 LST-S Subsystem Management (WP1220-1)

This main work package shall cover at least but not limited to the following activities:

- Project management.
- Systems engineering.
- Product assurance.
- Safety management.

These shall be intended as activities normally performed during the entire duration of the WP1220.

4.1.1.1 Project management

The Contractor shall implement effective and cost driven management for the project. The contractor shall appoint a Project Manager, who shall be responsible for the planning execution, control, and monitoring of the work to be performed; in the case of a consortium, the Project Manager shall coordinate and control the entire consortium's work.

The Contractor shall maintain project control and monitoring processes and metrics to compare actual project performance against the plans envisioned for the project. The Contractor shall assess performance till a level that permit to determine whether any corrective and preventive actions shall be taken and notified to INAF PO. Such notification shall include information on variance, status, and preventive/corrective plan.

The Contractor shall develop and maintain a schedule that details planned tasks and tracks actual achievements. It shall include task start and end dates and logical interdependencies (predecessors), including exchanges and/or logistics of configuration items (HW & SW) between major WBS elements, milestones, and deliverables.

The Contractor shall implement a process for risk management. As minimum, the Contractor shall identify, characterize, and mitigate both technical and managerial risks. The Contractor shall also track the status of risks, associated mitigation actions and opportunities. The risk management system shall include a risk register that shall also facilitates the classification and prioritization of risks for mitigation actions. The same principle shall be applied to safety related topics through a Hazard Analysis wherever necessary (e.g. during integration, tests execution, but also for telescope use and maintenance).

4.1.1.2 Systems engineering

The Contractor shall provide the System Engineering activity throughout the whole project life span.

The systems engineering, coordinated by the system engineer shall be responsible for preparing, maintaining, and updating all the technical documentation and mainly for leading and coordinating the different project working groups from the design phase to product delivery ensuring that all the requirements and goals are met with the expected quality level.

Moreover, the Contractor shall provide the interfaces as imposed by the HW which will be installed on the telescope; at the beginning there will be margins to optimize them only under INAF PO approval. In particular, the Contractor shall produce the ICD as requested in the AD01. The remaining interfaces to other systems (e.g. Camera, Calibration systems etc.) will be imposed to mount.

4.1.1.3 Product assurance

The Contractor shall plan, maintain, and implement quality assurance activities which can provide confidence that the quality requirements of the telescope mount will be fulfilled. The Contractor shall appoint a PA Manager, who is responsible of defining controls, monitoring, methods, and techniques to be adopted during the telescope mount development and implementation in order to assure a satisfactory degree of quality in the end-product.

The PA shall address or refer to all the provisions necessary to allow Product Configuration control. In light of this, the Contractor shall establish a configuration management system in order to keep traceability of all applicable documentation and monitor the traceability of each step in the development of the telescope mount. The configuration management system, to be implemented on the basis configuration management plan (already approved by INAF PO), shall ensure that:

- the as-built documentation is in line with the design documentation and is updated with the approved modifications,
- the delivered telescope mount complies with the as-built documentation,
- changes potentially affecting contractual documents shall be communicated through RFDs, RFWs or NCRs, and shall undergo a change control process handled in agreement with INAF PO,
- changes solely impacting the Contractor work shall be at least tracked and motivated in change records and justified by due analysis,
- changes records of configuration items shall be associated with configuration records (e.g. within a drawing set list).

Contractor PA activities shall also include the:

- control of critical items,
- coordination of quality audits and inspections,
- control of material and processes,
- management of alerts, and

- control of non-conformances.

The Contractor shall ensure that the applicable information items are available at the workplace and are adopted during the execution of the work required. Moreover, the PA provisions established by the Contractor shall be enforced to the sub-contractors to the extent needed for the proper development, implementation, and delivery of the telescope mount.

4.1.1.4 Safety management

The Contractor shall establish and maintain over the entire project duration an effective safety management system. This system shall be independent from other forms of project management to the extent necessary to prevent interference on safety matters. The Contractor's safety management shall have effective control, supervision, and support from experienced certified management staff. Personnel with proven experience shall be assigned to the LST-S telescope mount project, both for what concerns safety of the design and to guarantee and preserve compliance to local safety legislation during the various phases.

4.1.2 LST-S Subsystem Procurement (WP1220-2)

This main work package shall be subdivided in sub-work packages in order to cover as minimum (but not limited to) the followings:

- Engineering (design and analyses)
- Procurement management
- Infrastructure management
- Assembly Integration and Verification

Inside this work package are located all those activities that are aimed to design and develop the product till the integration and verification (as described in 4.3.4) of the telescope mount.

4.1.2.1 Engineering

The Contractor shall conduct and develop the telescope mount design throughout solid modelling, calculations, and analyses (e.g. FEA, CFD, servo analyses etc.) duly reported into documents to prove compliance to input design and analysis requirements.

For critical items, the Contractor shall foresee tests on prototypes and qualification activities to get feedback on feasibility and/or performance before procuring materials and components for the telescope mount implementation.

Moreover, the Contractor shall flow-down all specifications (e.g. dimensions, tolerances, thermal treatments, stress relief, surface finishing, welded joints characteristics, software blocks etc.) throughout drawings in order to guarantee successful implementation and integration of all components into the telescope mount. These specifications shall be updated according to the latest configuration till reaching their "as-built" state.

4.1.2.2 Procurement management

The Contractor shall define the procurement strategy in order to properly support the fabrication processes and associated logistic. The Contractor shall define supplier selection criteria for the identification of the most adequate suppling partners.

All the purchase orders, necessary to procure all material (including tools and packing) for the two telescope mounts shall be carried out by the Contractor and reviewed/accepted by INAF PO following the specifications developed during the activities performed at design and analyses level. During each of the procurement activities, quality shall be monitored accordingly throughout quality books reviews and specific audits.

4.1.2.3 Infrastructure management

The Contractor shall execute and manage entirely the factory infrastructure aimed for construction, sub-assembly, partial integration, inspections and tests at sub-system level. Moreover, the Contractor shall be responsible for the access to factory integration area, including the definition of safety rules and procedures in agreement with INAF PO.

4.1.2.4 Assembly Integration and Verification

After all items procurements (custom made, COTS and OEM items) the Contractor shall execute and manage all the activities to carry out the assembly of sub-systems. In case Option A is exercised by INAF PO, it shall also be included the integration and consequential verification for the first telescope mount at the Contractor's infrastructure prepared for this purpose. Once that telescope mount parts are integrated as foreseen, the verification shall demonstrate requirements compliance aimed to minimize the risks of activities on site (interfaces, functional and performance verifications); for this reason, a full telescope mount integration is **not** strictly mandatory as long as it is demonstrated that risks are acceptable and agreed with INAF PO.

4.2 WORK LOGIC

The required work has been divided in phases ending with defined milestones. This approach allows establishing decision gates that facilitate the control of the work. Moreover, to guarantee correct flow of the work, part of the activities is included by means of an option which can be exercised by INAF PO discretionally and unilaterally during the work execution.

In this case, for LST-S project they are subdivided in the following main phases:

- Requirement consolidation and system trade off (Phase 1)
- System & Product Design (Phase 2)
- Procurement (Phase 3)
- Factory integration and verification (Phase 4)
- Dismounting and packing (Phase 5)

With the following milestones:

- Kick Off Meeting (KOM)
- Preliminary Design Review (PDR)

- Final Design Review (FDR)
- Workshop Design Review (WDR)
- Procurement Review (PRC)
- Availability Review (AVL)
- Factory Integration Readiness Review (FIRR).
- Factory Acceptance Review (FAR) if Option A will be exercised by INAF PO.
- Shipping Readiness Review (SRR) if Option A will be exercised by INAF PO.

The option is the following:

- Option A: factory integration, tests, and packing ready for shipping to southern site.

The Option will be described within the phases and milestones descriptions.

The sequence and interconnection of the phases, milestones and option is described in the following Study Logic diagram:

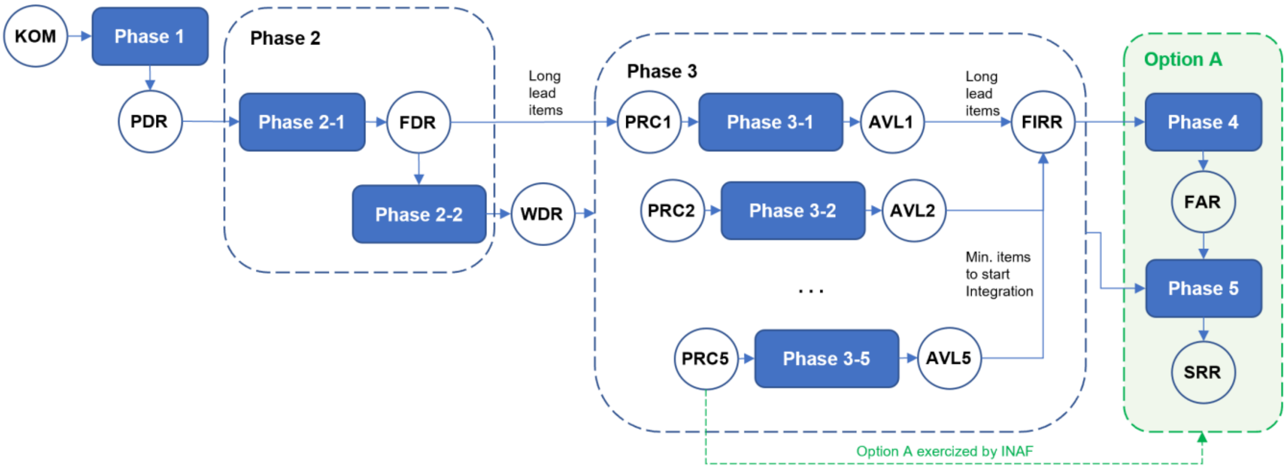

Figure 4.1 Work logic diagram with phases, milestones and option

4.3 PHASES

4.3.1 Phase 1: Requirement consolidation and System concept

Right after the Kick-off of the project the contracted work shall begin the analysis of the system and its specifications. This phase, through the consolidation of the technical requirements, shall lead to a fundamental trade off to be implemented in the next task. All the choices and technical evaluation will be discussed and validated with the Institute during the whole process. The phase ends with the completion of the first Milestone process (see 2.4.3) where a Preliminary Design Review (PDR) will be held for the verification and the delivery of the required documentation.

4.3.2 Phase 2: System and product design

The Design phase will primarily involve, in parallel, three different aspects: the hardware, the software, and the system general design. The design phases for the product, including the related documentations and results, will be divided in two stages: a final design stage (phase 2-1) and finally a workshop design phase (phase 2-2).

The final design phase shall freeze the design with all final calculations and models so to answer all design and analysis technical requirements applicable to the telescope mount. ICDs shall be frozen at this stage.

The workshop design phase consists in producing all the workshop drawings and bill of materials in order to procure all the items for the telescope mount.

The Contractor shall be responsible for the telescope mount design and its compliance, also through analyses and modelling, to the technical specifications (AD01). The minimum analyses and models required are the followings:

- Finite Element Analyses (e.g. static, modal, buckling, wind, earthquake, fatigue, thermal analyses) to assess structure functionality and performance,
- Computational Fluid Dynamic Analyses,
- Motion systems simulations (e.g. via Simulink modelling),
- RAMS to analyze LST-S life cycle (e.g. FMECA, fatigue, fault tree etc.), maintenance aspects, spare parts etc.

Regular weekly and progress meetings will be held throughout the whole design phase in order to gradually assess the design progress, and at the same time to mitigate the technical risks and to properly address them at an early stage.

The Contractor shall implement configuration management practices as defined in Contractor's Project Plan to control the configuration of Contractor's Design, associated requirements and deliverables (including documents, drawings, models, hardware, software, and support equipment).

4.3.3 Phase 3: Procurement

The production phase includes all the activities aimed at providing all the items, components, systems, and pre-assembled sub-systems, both COTS and custom-made, put in place ready for the integration.

The production phase, upon Contractor's proposal, can be articulated with multiple subsequent subtasks: Order submission & Contract preparation (the procurement of items) and Subsystems Availability & Verification (the items availability). Each subtasks pair (procurement and availability) can run in parallel and replicated up to a maximum of 5 pairs. At the end of any subtasks a related Procurement and Availability Review (PCRn, AVLn) will be held with associated Milestone.

For long lead items only, and in general for those items that can be finalized at the FDR, this phase may be started before the completion of the Workshop design if deemed useful by the Contractor.

The process described above aims at easing the implementation of an optimal strategy for minimizing the risks associated with procurement delays, cash flows, part machining, revision of critical parts. The Contractor shall be responsible for the procurement and fabrication of all parts explicitly stated in the previous section 3.1.

Each item, either HW or SW, shall be available for the consequent telescope integration at the end of the production phase. This means that sub-units must be already pre-assembled, verified through inspections and tests.

The availability of the HW or SW must be intended including all quality books providing all certifications to demonstrate state of the art production. The quality book shall be used to retrieve the entire traceability, following configuration management provisions. They shall include at least the followings (but not limited to):

- Material certificates.
- Thermal Treatments certificates.
- Welding certificates (operators, standard procedures, NDT certificates).
- Coating certificates (Surface treatments, paint thickness, etc.).
- Dimensional checks.
- Visual inspections certificates.
- RFWs, NCRs.
- SIL certificates.
- CE certificates.

4.3.4 Phase 4: Factory Integration and Verification (Option A)

The Contractor shall be responsible for all the activities necessary to pre-assemble and test the telescope on factory till the maximum extent possible (therefore, a full integration is **not** strictly mandatory), implementing the Test Plan produced by the Contractor and agreed with INAF PO. The main objective is to minimize the risks for the AIV activities on site through inspections and tests aimed to demonstrate that, the telescope potentially will meet all the requirements stated in AD01. Suggested test procedures may include partial structure pre-assembly, telescope main axes functionality (e.g. motion for pointing, slewing, parking, etc.) and all those functionalities that do not imply the use of equipment or parts out of the scope of this work (e.g. Mirrors, Camera, PCS, etc.). All test equipment needed to verify the requirements are meant to be provided by the Contractor and agreed with INAF PO at the Test Plan delivery.

During the entire phase, the Contractor shall be responsible for updating and providing quality books as the integration progresses. They need to include the followings (but not limited to):

- Bolt torque certificates.
- Visual inspections certificates.
- Inspection and Test reports.
- RFWs, NCRs.

In general, the quality books shall include all the certificates necessary to guarantee traceability over the entire assembly phase.

The Contractor shall be also responsible for all the activities (including relative documentation) foreseen to verify and validate the compliance of an item, a sub-system, or the system, through inspection and tests, during the entire duration of the contract, following the configuration management provisions.

The Contractor shall quote this phase, but its execution must be intended as an option (Option A) to be exercised unilaterally and discretionally by INAF PO if compatible with the schedule foreseen for PNRR activities. This option will be exercised by INAF PO not later than the last PRC milestone.

4.3.5 Phase 5: Dismounting and Packing (Option A)

After the successful completion of the AIV activities on the first telescope mount, the Contractor shall dismount it adequately in order to be packed for its delivery to site in Chile; moreover, all the items fabricated for the second LST telescope mount shall also be prepared and packed for their shipping to site.

All this packages and boxes shall need a storage area including also the boxes containing the mirrors, as per details reported in AD06. The storage facility/area on factory is part of this work till an extension of 12 months; after this period, it will be under responsibility of INAF PO.

This Phase is a direct consequence of the Phase 4 so it must be quoted, and its execution shall be considered as part of Option A.

4.4 MILESTONES

The Contractor management and development plans shall identify the deliverable documentation necessary to define task completion, specifically those linked to payment milestones. Generally, the Contractor shall submit invoices for milestone payments upon successful completion of milestone events which need to be approved by INAF PO through a Note. Milestone events may be successfully completed in advance of the date appearing in the milestone schedule. The contract documents will define the payment application process.

In the next paragraphs of this section, the scope of each review/milestone will be outlined along with a short description. At the end, the summary resuming the details of the deliveries is provided in tabular form (see 4.4.10); the table shall be considered as the reference in case of other documents or descriptions conflicts.

4.4.1 Kick-Off Meeting

The Contractor shall hold a KOM to provide the overview for the organization, personnel, and the plans to manage, control and develop the project in order to accomplish all technical and managerial requirements successfully. Moreover, the Contractor will produce all template and format in order to be approved by INAF PO.

Finally, the Contractor shall perform a detailed analysis of the requirements summarized in the technical specifications (AD01) in order to prepare a Compliance Matrix to address all requirements. The Compliance Matrix shall stress the critical points and risks which will be recorded on the Risk Register along with mitigation strategies.

4.4.2 Preliminary Design Review

The Contractor shall develop an overall preliminary system design of the LST-S mount based on the Compliance Matrix agreed at KOM using trade-offs wherever necessary.

The aim of this review is to freeze technical solutions to be used during LST-S design; to address this task it will be essential for the Contractor to develop:

- 3D models with all volumes and interfaces assigned,
- Preliminary design description,
- Preliminary error budgets,
- Preliminary analyses (FEA, CFD, Simulink etc.)
- Preliminary procurement, manufacturing, assembly test and inspection, maintenance plans.
- Preliminary ICDs definition.

Those shall be used to prove concept compliance to Technical Requirements. Since the design will not be complete, it will be essential to update the risk register with all the risks envisioned during this phase. The meeting will focus on design and critical risk areas and those requiring decisions by the INAF PO and the Contractor to enable the completion of design work.

In addition, the Contractor shall perform a detailed review of interfaces provided by INAF PO. At the same time, the Contractor shall produce the ICDs assigned by the technical requirement document (AD01). The intent is to confirm responsibilities and need dates and coordination completion of ICDs to minimize potential rework and schedule delays. Moreover, it is essential that the foundation design concept shall be defined and preliminary drawings available.

4.4.3 Final Design Review

The Contractor shall develop a Final Design Review using the technical solution defined at Preliminary Design Review stage.

The aim of this review is to perform the design and analyses which prove the telescope mount design full compliance to technical requirements. For these reasons, the following must be completed:

- 3D model,
- Design description,
- Error budgets,
- Analyses (FEA, CFD, Simulink, RAMS etc.).
- Procurement, manufacturing, assembly, test and inspection plans.
- ICDs definition.

The design in this case shall be frozen also to define long lead items in order to start their procurement and optimize their delivery time to have them available when acceptable.

Having a final frozen design of LST-S implies that the interfaces require to be completely defined as well. Consequently, the ICDs set must be frozen, mutually compliant and agreed with the relative stakeholders.

Risk register at this stage shall be updated with all the mitigations already implemented to complete the design and analyses phase. All risks retrieved by the analyses performed during the plans production shall be updated accordingly.

At this stage the foundation construction drawings shall be entirely available to allow INAF PO to proceed autonomously with foundation building on site (construction **not** included in the scope of this work) and review all details about storage facility/area.

4.4.4 Workshop Design Review

The Workshop Design Review will take place after the production of the fabrication and workshop drawings for the design presented at the Final Design Review. The following documents shall be updated according to some minor deviations that can occur during the drawings set production:

- Updated Procurement, manufacturing, assembly, test, and inspection plans.
- RAMS analysis update (for details arisen during drawings production).
- Preliminary Packing and Shipping Plan.

4.4.5 Procurement Reviews

The Contractor shall provide the entire set of documents necessary for the procurement of all items. In particular:

- Provide evidence of outsourcing signed outsourcing contracts,
- Procurement Data Packages.
- Packing and Shipping Plan.

To ease cash-flow and the management of the items the procurement phase can be split till a maximum of 5 logic groups (as described in 4.3.3). The list must be clearly referring to the PBS in order to avoid any misunderstanding. It is Contractor's choice to define logic groups content; for example, it could be more convenient to split logic groups with PBS criteria for both telescopes or in a "first and second telescope mounts" parts.

In case the plans foresee to entirely or partially manufacture custom made parts at the Contractor premises, intermediate procurement stages can be considered before items availability if they can be clearly identified. The quality book in this case will reflect the partial status of the item production. As example, if a structural item machining is performed in house while steelwork welding before that is provided by a third party, material, thermal treatments, and welding certificates must be included at this stage.

At the last Procurement Review all details shall be clear to allow INAF PO to exercise the right to proceed with the factory integration and test (Option A).

4.4.6 Availability Reviews

When the items procured and/or manufactured in logic groups during the procurement phase are available for their integration into the telescope mount the milestone is achieved. Every logic group shall have its separated availability milestone to grant correct cash flow and correct logic of workflow.

The last logic group shall be completed including the integration procedures along with the presence of all the quality books relative to the procurement of parts ready to be integrated into LST-S telescope mount.

The As-built drawings set shall be produced to reflect the production and assembly details not included in the drawings previously.

4.4.7 Factory Integration Readiness Review

The Factory Acceptance Review will take place when the first LST-S telescope mount sub-systems are available and ready to be integrated in factory. It must be noted that, the availability of all items must be intended valid not only for hardware but also including software beta version. Software is considered an essential and critical part of the telescope mount deliverables.

The telescope mount integration hazard analysis as well as all assembly and test procedures must be completed at this stage, so to be sure the risks are minimized, and integration can potentially start.

4.4.8 Factory Acceptance Review (Option A)

The Factory Acceptance Review can take place when the LST-S telescope mount is integrated and tested in factory. In this milestone it shall be necessary to also provide the SW completely available and commissioned and all the quality books update after integration implementations.

The Contractor shall produce test and inspection reports in order to formally state the compliance of the technical requirements as well as a version of the As-built drawings set after integration and verification.

4.4.9 Shipping Readiness Review (Option A)

The Shipping Readiness Review can take place when the LST-S telescope mount is dismounted and packed properly, ready to be shipped to Site (Chile).

To complete the documents set included in the scope of the entire work the following documents shall be included as essential:

- As-built drawings set after integration and verification.
- All quality books.
- Test and inspection reports updates including packing details.
- User and maintenance manuals shall be provided to grant correct information flow to final user.

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4.4.10 Milestones summary table, deliveries and schedule

Here is provided a comprehensive table for the Milestones showing the correspondences with Reviews and Deliverables and the associated expected schedule.

Furthermore, this table provide the schedule and the associated deliveries requested for each of the milestones.

DESCRIPTION		KOM	PDR	FDR	WDR	PRC	AVL	FIRR	FAR (option A)	SRR (option A)
SCHEDULE		T0+1M	T0+3M	T0+6M	T0+9M	max 5 stages TBD	max 5 stages TBD	T0+18M	T0+21M	T0+22M
HW & SW										
	HW availability					TBD	TBD	X	Integrated	Accepted
	SW availability					TBD	TBD	Preliminary	X	Accepted
DOCUMENTS										
PLA	Project Management Plan	X								
PLA	Development Plan	X								
PLA	Schedule	X	Update	Update	Update	Update	Update	Update	Update	Update
LIS	Cost breakdown	X	Update	Update	Update	Update	Update	Update	Update	Update
PLA	Safety Plan	X			Update			Update		
PLA	Risk Management Plan	X								
LIS	Risk Register	X	Update	Update	Update	Update	Update	Update	Update	Update
LIS	Compliance Matrix	X	Update	Update	Update		Update	Update	Update	Update
PLA	Product Assurance Plan	X								
PLA	Configuration Management Plan	X								
ICD	Interface Control Documents		Preliminary	X						
MDL	3D models		Preliminary	X						
DWG / BOM	Workshop drawings and Bills of Material		Preliminary Foundation drawings	Foundation drawings	X		Fabrication As-built		Preliminary Integration and Verification As-built	Integration and Verification As-built
TRE	Design description (including error budgets)		Preliminary	X						
TRE	SW release version report					Preliminary	X		Update	
MDL / TRE	FEA		Preliminary	X						
MDL / TRE	CFD		Preliminary	X						
MDL / TRE	Motion systems simulations		Preliminary	X						
TRE	RAMS Analysis		Preliminary	X						
PLA	Procurement plan		Preliminary	X						
PLA	Assembly plan		Preliminary	X				Update		
PLA	Test and inspection plan		Preliminary	X						

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DESCRIPTION		KOM	PDR	FDR	WDR	PRC	AVL	FIRR	FAR (option A)	SRR (option A)
PLA	Maintenance plan		Preliminary	X						
LIS	Procurement Data Packages			Long Lead items	X					
LIS+Annexes	Outsourcing contracts					X				
LIS+Annexes	Quality books						X	Update	Update	
PLA	Packing and shipping plan			Preliminary	X		Update			Update
LIS	Telescope integration hazard analysis				Preliminary			X		
PRO	Assembly procedures					Preliminary	X			
PRO	Test and inspection procedures					Preliminary	X	Update	Update	
TRE	Test and Inspection reports						X		Update	Update
MAN	User manuals						Preliminary			X
MAN	Maintenance manuals						Preliminary			X

5 RESPONSIBILITY & CUSTOMER RIGHTS

5.1 INTELLECTUAL PROPERTY AND DOCUMENTATION OWNERSHIP

All documents, models and ideas produced during the development of this effort will be owned by INAF including the intellectual property. At the end of this work, INAF is authorized to use, modify and distribute the documents and their content.

In case the Contractor uses a pre-existing intellectual property (“background”) of his own, that shall be declared explicitly, and can be used by INAF PO exclusively for LST South project preserving the ownership.

Finally, the Contractor shall assure that all intellectual properties used, is not harming any other third party.

5.2 PRODUCT ASSURANCE RECORDS

INAF PO shall have unrestricted access to PA records, certificates, incoming inspection protocols, etc., which if not to be delivered as part of the planned data packages, shall be available for review and audits as deemed by INAF PO. The audits can be conducted at Contractor’s and/or Sub-contractor’s promises, at INAF PO’s discretion. At the end of the work, the entire quality books data base shall be handed over to INAF PO.

5.3 FACILITIES ACCESS

The Contractor shall provide general site access to their facility, including its subcontractor’s ones, where LST-S activity is specifically occurring for INAF individuals (including third parties explicitly appointed by INAF) identified and pre-authorized by both parties during normal business hours and operations. INAF individuals, (and all third parties personnel appointed by INAF) will comply with all Contractor safety rules and facility policies.
The Contractor shall provide the INAF PO with facility phone and internet capabilities adequate to support technical interactions as necessary and access to observe testing as required.

6 ANNEX 1: DOCUMENT REQUIREMENTS DEFINITION

6.1 MANAGERIAL DOCUMENTATION

6.1.1 Project management plan

The document shall address the following minimum set of information:

- Organizational breakdown with organogram and responsibilities, key personnel (key roles and WP roles).
- Tools and processes for project control, coordination, and monitoring.
- Main Suppliers foreseen and their management.
- System Engineering related topics:
  - Requirements and how to grant their compliance (analyses, means and tools used to design and produce HW and SW etc.).
  - Interfaces and how to guarantee successful communication between parties.
- Moreover, Project management plan should provide the link to the followings:
  - Development plan (see section 6.1.2).
  - Safety plan (see section 6.1.8).
  - Product Assurance plan (see section 6.4.1).
  - Risk management plan (see section 6.1.4).

6.1.2 Development plan

The document shall contain the following minimum set of information:

- Product Breakdown Structure (PBS), based on the one provided in section 3.1 but extended till level 4.
- Work Breakdown Structure (WBS) which is a logical tree structure breakdown defining the activities that must be performed to achieve the Project objectives and accomplish the scope of this work. The breakdown shall correspond to clearly identified deliverables to be generated (product, documentation, etc.). The elements of the lower level, once assembled, shall reconstruct the higher-level element.
- Project Phasing: a Project workflow of how the Project has been decomposed into sequential phases with the anticipated top level Project life-cycle gate reviews (preliminary analysis, definition, design, development, qualification, production, assembling, integration, verification, etc.). WBS activities shall be logically grouped in Work Packages in function of the Project phase.
- Work Package Descriptions (WPDs): a WP description containing the following minimum set of information:
  - WP Title;
  - WP Responsible;
  - WP number
  - WBS items included;
  - Inputs and link to other WPs;
  - Description of the work;

  - Outputs and link to other WPs;
  - List of deliverables, title of each deliverable, delivery date, type of deliverable (e.g. Report, Product, etc.);
  - Excluded Tasks;
  - Total effort in man hours;
- Reference to Schedule (see section 6.1.3).
- Moreover Project development plan should provide the link to the followings:
  - Procurement plan (see section 6.6.1).
  - Assembly plan (see section 6.6.2).
  - Test and inspection (see section 6.6.3).
  - Packing and shipping (see section 6.6.4).

6.1.3 Schedule

The document shall contain the Master Schedule of the project which includes the activities/tasks in Gantt Chart form with:

- the dependencies between activities
- an up-to-date status of the Project and the critical and sub-critical path highlighted,
- the percentage of task completion,
- the buffer time explicitly stated,
- the identification of normal working conditions (working and non-working periods).

6.1.4 Cost breakdown

The document shall contain the breakdown of the cost for:

- Each phase broken down till level 2 of WBS subdivided by labor and equipment.
- Items as per PBS till level 3 (see section 3.1).

6.1.5 Risk management plan

The document shall contain the following minimum set of information:

- Project objectives (in terms of cost schedule in order to assess the scoring scheme).
- Risk scoring scheme (severity and likelihood).
- Risk index definition (based on the risk scoring scheme).
- Mitigation actions (based on Risk index).
- Risk acceptance criteria.
- Risk comparison methods (to assign risk priorities).
- Risk monitoring (risk assessment and risk register).

6.1.6 Risk register

The Risk register shall list all the Project level risks identified during the execution of the contract. Updates of the Risk register shall be transmitted to the INAF PO along with the Progress report. It shall list in a tabular format as a minimum:

- A unique risk identification reference.
- Risk source originator (e.g. Progress Meeting Review, etc.)
- Risk identification date.
- Description of the risk.
- The risk owner.
- Risk index (assessed as indicated in Risk management plan).
- Status (e.g. open, mitigated, occurred, retired).
- The current prevention/mitigation actions identified.
- The due date for the implementation of prevention/mitigation action foreseen.
- Mitigated risk index.

6.1.7 Note

The Note is a short document/letter reporting a topic of managerial or technical nature normally used for official communications. Typical examples of use are:

- Notification of successful completion of milestone.
- Notification of a major problem which has the potential to seriously affect the performance of the Contract and demanding immediate knowledge and attention of the parties.
- Notification of an opportunity to improve performance, cost and/or schedule.

The Note must have a simplified template indicating the originator, the recipient, and the description of the content.

6.1.8 Safety Plan

The document shall contain the following minimum set of information:

- The safety management approach and methodology to be used throughout the entire duration of the project, with specific chapter for the integration of the telescope and its verification.
- The safety organization structure indicating the structure of the different levels of responsibilities and authorities involved in project safety (including Contractor activities).
- Communication and reporting: safety management communication, planning, and control.
- Hazard identification and tracking principles.
- Safety monitoring process (e.g. audits with sub-contractors, hazard analysis report, accident report etc.).
- Training of the personnel.

6.1.9 Hazard analysis report

Each of the activity performed during the development of this work, but also the use of the product and its sub-products shall be assessed; if safety is potentially involved this assessment must be done within the Hazard analysis report. This document shall include the following minimum set of information:

- Description of the Subsystem/activity.
- Hazards list subdivided in categories such related to:

  - adopted design,
  - activities before telescope use,
  - lifetime operation and maintenance.
- Assessment of the Hazard Priority Numbers including severity of the effect, likelihood of occurrence and ability of detection.
- Explanation of the Hazard reduction measures adopted including input to operation and/or maintenance Procedures.
- Prove that residual hazards are acceptable.

6.2 SYSTEM ENGINEERING DOCUMENTATION

6.2.1 Compliance Matrix

The plan and status of requirements verification shall be done through a Verification or Compliance Matrix with the following set of information in a tabular format, (as a minimum) :

Req. ID	Req. Description	Design (D)	Analysis (A)	Inspection (I)	Test (T)

For each requirement that has to be verified:

- The requirement ID.
- The requirement description.
- The combination of the selected verification means references.

The Compliance Matrix shall, at the beginning of the project, recapitulate for each requirement, the means or process plan of verification that the Contractor intends to adopt to successfully comply with it. These plans must be reported under the Design, Analysis, Inspection and/or Test columns. Any deviation between the minimum set of Verification means required by the INAF and the ones proposed by the Contractor shall be clearly highlighted for each requirement.

During the development of the work, for each of the requirement the plan shall be replaced with the reference document demonstrating its compliance status (including NCRs etc.). Each of the reference documents shall state explicitly “compliant to req. n°…” in the exact location where the description or the calculation demonstrates the requirement compliance in order to easily allow a cross check.

6.2.2 Interface Control Document

These set of documents are specifications which shall contain the following minimum set of information:

- The sub-systems (or WPs) involved and the master/slave relationships. The “master” entity shall write the document in order to provide all input details that put the “slave” entity in the condition to comply with the interface and provide an output that matches accordingly.
- Description of all interfaces (by means of HW description, functionality, drawings etc.) capable of ensuring LST-S telescope mount full functionality and performance.

- The interfaces shall be listed as individual requirements.

ICDs compliance must be reported in the Compliance Matrix (see section 6.2.1).

6.3 MONITORING DOCUMENTATION

6.3.1 Action Item List

The Contractor shall be responsible to track the actions discussed during the development of the work. Those should be enclosed in a document in list form with at least the followings:

- Unique id for the action.
- Action source: minute, note or email.
- Description.
- Responsible of the action (actionee).
- Due date/closure date (closure date can replace due date or it can have a dedicated field).
- Solution source: minute, note or email.
- Action status (open, closed, retired).

The list shall be always available for INAF PO (in shared mode).

6.3.2 Agenda and Minute of Meetings

Each meeting foreseen in the scope of this work needs an agenda of topics to be discussed. The Contractor shall at least:

- Send the agenda via email in advance in function of the meeting type,
- Provide a list in bullet form with the description of topic to be discussed.

During the development of this work, for each and every meeting the Contractor shall produce a relative minute in a simplified template to grant correct traceability. This document needs:

- To include the agenda sent via email.
- To include participants.
- To include clearly:
  - actions with due date and responsibility,
  - decisions,
  - statements.

Each minute needs to be approved and signed by all parties involved at the end of the meeting unless otherwise decided by INAF PO.

6.3.3 Monthly progress report

The Contractor shall provide written monthly progress reports. Monthly reports shall be delivered via email and shall highlight progress and activities performed the previous month (including model images, analysis outputs, pictures, etc.), report on status of action items, identify new problems or issues for tracking and resolution, and provide a look-ahead of major activities and tasks planned for the upcoming month. In summary:

- Report of activities (in list form) done in the last month.
- Action items status table (number of open AI, closed etc.).

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- PA status table (NCRs, RFDs, RFWs, CREs status)
- Major risks arose and mitigations.
- Report activities for the upcoming month.
- Attachments: Up to date Schedule, Action Item List, and Risk register.

6.4 PRODUCT ASSURANCE DOCUMENTATION

6.4.1 Product assurance plan

The product assurance plan shall present the project product and Quality Assurance organization, methods, tools and procedures that the Contractor intends to implement for the project.
The document shall contain the following information as a minimum:

- Quality Assurance: functions organization and work tasks.
- Quality books content descriptions in function of the work phase and product.
- Configuration management: link to the Configuration Management Plan.
- Reviews and Audits: Scheduled and non-scheduled.
- Sub-tier Contractors Control: Assurance that requirements, standards, and controls imposed on the equipment manufacturers are imposed also on the lower-tier manufacturers as applicable.

6.4.2 Configuration management plan

The Configuration management plan shall outline the organization and the means (methods, tools, and procedures) throughout it is necessary to handle product changes and the interfaces internal and external to the Project. Based on this plan, a Configuration management system shall ensure that:

- The manufacturing documentation is in line with the design documentation.
- The product is in line with the manufacturing documentation.
- Required design, item, or component and/or manufacturing non conformance, deviation waiver or change is properly analyzed approved and documented to be established by the Contractor and agreed by INAF PO.

Finally, the configuration management plan shall address as a minimum:

- Configuration management responsibilities and authorities.
- Configuration control and change process (NCRs, RFDs, RFWs and changes).
- Configuration identification and status accounting.
- Configuration Audits.

6.4.3 Non-conformity report

During the project development the Contractor shall immediately report any non-conformance to the INAF PO. No remedy shall be allowed until approval is granted from INAF PO. The formal contract change request process is detailed in the contract document.

The Non-Conformity Report shall include in a schematic, simplified template a set of information equivalent to the one listed here below:

- Initiator and date of detection.
- The reference of the requirement, document, or item (CI and serial number).
- The description and reason of the NCR observed.
- Analysis of the root cause and if it is recurring.
- Effect description.
- Decision about how to address the non conformance (action, rejection, implementation of RFD, RFW or CRE).
- Approval (e.g. by INAF PO) of the decision proposed.
- Verification by PA.
- Closure.

6.4.4 Request for deviation

During the project development the Contractor may submit a Request for Deviation prior to the manufacture of an item seeking a planned variance from specified requirements.

The minimum set of details is equivalent to the one outlined in RFW section; in RFD case the corrective action is not foreseen as the deviation is not submitted after manufacturing.

6.4.5 Request for waiver

During the project development the Contractor may submit a Request for Waiver to accept an item which, during manufacture or after inspection, was found to depart from specified requirements, but is considered suitable for use as is or after rework by an approved method. Neither waiver shall be allowed until reviewed and granted from the INAF PO.

A RFW shall include in a schematic, simplified template the following information as a minimum:

- Initiator information.
- Configuration Item (CI) to be covered by the waiver.
- Serial number of the affected instances or batch number, etc.
- The affected Documents/Drawings/Requirements.
- The description and reason of the RFW.
- Impacts on:
    - technical aspects such as feasibility, function, performance, reliability, maintainability, or interfaces.
    - Schedule of key milestones (including detailed schedule of the change implication).
    - Costs (giving detailed information on the manpower, material, cost etc. and reflecting the differential cost for changes in work packages).
    - Safety of the system.
- The corrective action taken by the Contractor.
- The price concession proposed by the Contractor.
- Additional documents as needed to justify the RFW (e.g. NCR).

6.4.6 Change request

Any changes or non-conformance that affect technical requirements, schedule, or cost shall only be authorized through written notification from the INAF PO contractual point of contact and the Contractor. The formal contract change request process is detailed in the contract document. Issues not affecting performance, schedule, or cost will be addressed individually.

A CRE shall include in a schematic, simplified template at least the following information:

- Initiator information.
- Affected Configuration Items (CIs).
- Affected Documents/Drawings/Requirements.
- The description of the change by means of a clear indication by quoting the old and proposed new versions of the document text or the drawing.
- The reason for the change and expected benefits.
- Impacts on:
  - technical aspects such as feasibility, function, performance, reliability, maintainability, or interfaces.
  - Schedule of key milestones (including detailed schedule of the change implication).
  - Costs (giving detailed information on the manpower, material, cost etc. and reflecting the differential cost for changes in work packages).
  - Safety of the system.
- Additional documents as needed to justify the CRE (e.g. NCR).

6.4.7 Configuration Item Data List

The Configuration Item Data List (CIDL) shall list all the up-to-date applicable documents relative to a specific CI at one moment in time of the project. It shall contain as a minimum:

- CI identification (part number and serial number - where appropriate).
- List of the technical specifications.
- List of the ICDs.
- List of the design/analysis reports.
- List of the drawings.
- Bill of Material (BoM).
- List of plans.
- List of procedures.
- List of manuals.
- Quality books.
- List of software.
- List of NCRs and already approved RFDs/RFWs, CREs.

All documents shall be recorded in the CIDL as a minimum with their code, issue, title, and release date.

6.5 DESIGN DOCUMENTATION AND MODELS

6.5.1 Design descriptions

6.5.1.1 Design report

The Design report shall describe all the design aspects of all items and disciplines subject of the work. The effective way to do so, is to address each requirement reported in the technical specifications and as applicable to the item/discipline subject of the Design Report.
In particular the Design report shall contain, as a minimum:

- the scope, establishing the boundaries of application of the document and stating explicitly what is covered and not covered.
- Applicable and reference documents in order of mention throughout the report.
- The assumptions like design requirements (e.g. environmental), maintenance requirements (if applicable), access requirements (if applicable), all calculations methods (if applicable), etc.
- The materials and coating used in the design, their physical, mechanical, and chemical properties when required.
- The Design description addressing explicitly every requirement specified in the technical specifications. Every time a requirement is satisfied by the descriptions, it shall be essential to explicitly state "compliant to req. n°…".
- Reference to specific analysis report to support every design solution.
- Calculations supporting the design, others than those included in the analysis reports.
- Non-conformities.

6.5.1.2 Software design report

This document shall provide the description of the design for the control software program, with traceability between software requirements and their implementation.
It shall include, as minimum, the following information:

- A description of the program structure (design trees) and blocks partitioning.
- Data flow diagram.
- Program control flow diagram.
- Descriptions of data and control interfaces between software blocks and between software and hardware.
- Description of algorithms.

6.5.1.3 Analysis report

The Analysis Report shall include calculations which support the design (e.g. FE models and calculations, CFD Analyses, dynamic and servo simulations, thermal exchange Analysis, RAMS etc.). An Analysis Report shall be produced every time verification by Analysis is required by the Compliance Matrix, unless is not supported by calculations present in design reports.

The Analysis Report shall contain the following information, as a minimum:

- the scope identifying against which issue of the specification and/or design or manufacturing configuration the Analysis has been performed.
- Applicable and reference documents in order of mention throughout the report.
- The assumptions like design constraints (e.g. environmental), maintenance constraints (if applicable), access constraints (if applicable), all calculations methods (if applicable), etc. In particular, assumptions used for:
  - the definition of the model,
  - boundary conditions (if applicable),
  - material properties (if applicable),
  - defining inputs, loads and loading cases (if applicable),
  - processing the results (if applicable),
  - the definition of stiffness, damping, masses and inertia (if applicable),
  - the thermal exchange coefficients (if applicable),
  - any other assumption,
  - analysis methods.
- Model used in the Analysis shall be described in detail (e.g. geometry, diagrams, elements properties, boundary conditions, loads topology, inputs, type of elements or block used, type of components used, correspondence between the model and the actual modeled components). Plots and sketches illustrating the model shall be included in order to allow the model reproduction.
- Scenario or loading cases illustrated by means of plots and/or sketches. The list of the loaded entities (e.g. nodes) shall be given if applicable.
- Results obtained from the analysis by means of plots and numerical values shall be processed in order to be directly comparable with the verification items.
- Non-conformities.

6.5.2 3D Model

The 3D model shall be produced considering the followings:

- Each item (custom and COTS) should be modelled adequately, representing its volume and functionality aspects by means of CAD system.
- The sub-assemblies shall be produced including the full set of items foreseen as if they are mounted in their final configuration. Motion between parts shall be possible to assess potential issues. Preliminary assembly models shall take into account volume of items that are not defined yet.
- The LST-S system shall be modelled using the sub-assemblies wherever possible or simplified models (or volumes) which include all necessary internal and external interfaces. In case of use of simplified models of volumes, envelopes of their possible motion positions shall be provided.
- All those items or systems that cannot be modelled, partially or completely, to describe their functionality through volumes will be provided in agreement with INAF PO through drawings and/or schematics or diagrams. For example:

- fluidic systems shall be documented in Piping and Instrumentation (P&I) diagrams with proper item and location referencing as used also in the other related Project documentation.
- Electric and electronic systems shall be documented by functional/architecture diagrams and wiring diagrams based on IEC 81346 with proper item location and referencing as used also in the other related project documentation.

6.5.3 Workshop drawing set

The workshop drawing set shall define the specification (materials, treatments etc. as defined in the design) for the production and assembly of all deliverable items, including support equipment, in all engineering disciplines to the level of detail necessary for the manufacturing and/or assembly at workshop and/or site. The workshop drawing set shall include also the “Drawing List” including all drawings with their revision number (including the As-built drawings).

Excerpt of Data sheets of Commercial off-the-shelf (COTS) items shall be provided as documents listed in the CIDL and shall be included in the workshop drawings set labelled with proper reference to the part number used in the BoM or parts list.

The Assembly drawings shall always report in a tabular format the associated “Part List” within the drawing; it shall contain as minimum:

- Item Position: structure level in the BoM hierarchy (starting with 0 for the top level of the assembly being described)
- Identification Label:
  - Custom item: CI.
  - COTS: Manufacturer and Manufacturer’s identification code.
  - Original Equipment Manufacturer (OEM) items: for norm parts e.g. screws, washers etc., the dimensions shall be provided (e.g. for a screw: M8x20 ISO 4017).
- Description: Brief description of the item for OEM or COTS parts while CI description shall be used (possibly equivalent to the one used on PBS).
- Quantity: number of pieces used in the assembly or subassembly.
- Material, thermal and surface treatment.
- Mass: information shall be provided at least at Assembly Level.

Each Part List shall be exported into BOM. In some specific cases where it is not practical and/or feasible to report the part list into assembly drawings, BOM will be sufficient (e.g. electrical cabinets with a long list of items).

6.5.4 Bill Of Material

The BoM shall be delivered in the form of a hierarchical multi-level BoM and the Part List shall be delivered as a single level list.
Each subassembly shall be listed along with the components that make up that subassembly.
An individual part may be listed in the BoM multiple times if it is included in more than one subassembly.

6.5.5 FE Models

The global Finite Element model shall be entirely described in a dedicated analysis report (see 6.5.1.3). The LST-S structure and all its parts must be modelled making reasonable assumptions that make it behave as close to reality as possible. This model shall be used to retrieve static, dynamic, survival performance. Guidelines on how to obtain these models are present in AD07.

Local models can be used wherever necessary to assess specific items behavior and study their functionality, feasibility and/or performance.

6.5.6 CFD Model

The Computational Fluid Dynamics model shall be entirely described in a dedicated Analysis Report (see 6.5.1.3). This type of modelling shall assess the magnitude of wind loads on the structure; the loads shall be used as input for FE analyses to evaluate the effects of the wind on the LST-S structure in operational and survival conditions.

6.5.7 Motion system Model

The Motion system model shall be entirely described in a dedicated Analysis Report (see 6.5.1.3). This type of model shall be used in simulation assessing the behavior and performance of the structure during observation (e.g. pointing, tracking, and settling time). This model shall take into account the type of motors, drives, encoders, and all the key elements part of the motion loops; structure stiffness shall be applied taking into account where loads and key elements are located.

6.5.8 Reliability Availability Maintainability Analysis

The RAMS analysis shall contain as a minimum:

- Description of the System under examination and decomposition in LRU.
- Assumptions.
- Methodology used (e.g. Parts Count method as per Handbook like MIL-HDBK-217F or Siemens SN 29500).
- Reliability data sources (e.g. Non-electronic Parts Reliability Data (NPRD)-95).
- Prediction of Reliability and Availability based on failure rates data.
- Preventive replacement time for components in a repairable System.
- Spare parts requirements and production rate, spare parts list.
- Mean Time Between Failures (MTBF) computation.
- Down time of the Product and its availability taking into account the MTBF, Mean Time To Repair (MTTR) and the Time for Preventive Maintenance.

Furthermore, the report shall contain or make reference to the following:

- Failure Mode Effects and Criticality Analysis (FMECA).
- Fault Tree Analysis (FTA).
- Reliability Block Diagrams (RBD).
- Telescope Mount use and maintenance hazard analysis (see 6.1.9).

6.5.8.1 Spare part list

The spare part list shall contain all the information related to the spare parts and the consumables necessary to operate and maintain the Product throughout its entire lifetime.
The Spare Part List shall include as a minimum:

- Parts labelled with CI, COTS, or OEM name.
- Consumables with associated quantities, item name and vendor(s) name and contact details.

Each of these shall report:

- associated Vendor(s) name and contact details, address, website, etc.
- For COTS and OEM items, additional specifications not retrievable by their identification label.
- Recommended amount of spare parts taking into account the findings of the RAM Analysis and the information provided in the Maintenance Manual.
- Overall dimensions.
- Delivery times.
- Expected lifetime on the shelf.
- Storage conditions and special storage prescription (power up, no direct sunlight, etc.).

6.6 PROCUREMENT ASSEMBLY INTEGRATION & TEST DOCUMENTATION

6.6.1 Procurement plan

For the purpose of the LST-S Project the procurement plan shall list the major activities that are planned for the purchase and/or manufacturing of the Product and the associated activities foreseen for inspection, pre-assembly, testing of the items, starting from the components up to the parts and assemblies which complete the entire Product. The following minimum set of topics shall be covered:

- Manufacturing process qualification: explaining how the manufacturing process capability will be selected, achieved, and maintained.
- Manufacturing facilities and location (including sub-suppliers) including a description of the type of production, types of machinery available, etc.
- Expected procurement block diagrams when single activities on the same assembly involves more suppliers (e.g. Raw material purchase by supplier A → Manufacturing by Supplier A → Welding by Supplier B → Thermal treatment by supplier C → Coating by supplier D → Assembly in house).
- Transportation details between different sub-suppliers.
- Expected manpower during execution.
- Constraints on procurement or deliveries.

6.6.2 Assembly plan

The assembly plan shall describe the sequence of the assembly and integration procedures for the factory assembly activities. To this purpose a PERT diagram may be used.

The Plan shall list all steps of assembly of sub-systems and integration on telescope. It shall also refer to the major procedures to be used for assembly, alignment, inspections, checks stating explicitly all critical operations performed during the assembly and integration process.
Moreover, the plan shall include:

- Handling equipment.
- Standard tools and machines.
- Special assembly tools.
- Available measuring and alignment equipment.
- Manpower (amount, qualifications, and categories).
- Office and workshop features.

6.6.3 Test and Inspection Plan

The test and inspection plan shall outline a table listing the inspections and tests titles identified with a unique label.

The tests and inspections descriptions shall be in paragraphs named with "Test and Inspection Title" and shall contain the following set of information, as a minimum:

- Unique dentification label.
- Reference to the requirements covered.
- Assembly Level (e.g. product tree level) and the configuration (e.g. involving dummies).
- Description and objectives.
- Inputs, outputs.
- Success criteria.
- Authority performing the test/inspection (e.g. Test Engineer, etc.).

6.6.4 Packing and Shipping Plan

This plan shall identify all the transportation phases and the unloading/loading milestones for transportation of the product from the Contractor premises to the final site in Chile.
The document shall have a first section which shall describe the followings:

- Packaging means shall be identified highlighting the rationale that has been used for the selection of the packaging type (fragile items, etc.)
- Types of code markings that will be used, marking information (e.g. fragile/delicate, arrows, hazardous warning labels, use no hooks labels, etc.)
- Handling means indicating handling tools (if applicable).
- Storage means.
- Loading/Unloading Operations.
- All supervision activities that will be taken to verify that the products are correctly presented, properly handled, and safely secured on the means of transport.

The second section shall focus on the shipment plan proper, with identification of the major shipment, loading and unloading points, transportation means anticipated, schedule etc.

Furthermore, it shall be detected, listed and analyzed the areas that might cause or entail delays. For this reason, a risk register shall be updated, and references provided.

6.6.5 Procurement Data Package

They are the specifications, at all levels of the Project, that define the units and major subunits that will be prepared by the Contractor or/and by the Subcontractors. The Procurement Data Packages shall contain, as a minimum:

- Lower level Specifications (including Item description, physical data, Interfaces, environmental, functional, non functional, performance, requirements etc.)
- Applicable documents
- Output required.

Traceability between requirements shall be provided, e.g. between requirements derived by other specification (upper level) and the lower level specification (requirement flow-down, allocation, decomposition, etc.)

6.6.6 Outsourcing contracts

A list of the contracts to supply a partial delivery of the present scope of work outsourced to sub-Contractors shall be submitted in list form to the INAF PO. Each of these contracts with the signature from both parties involved shall be attached to the contract list. Monetary data can be censored adequately.

6.6.7 Quality books

The quality books shall be used to have the entire traceability of the HW and SW produced. In function of the phases, they shall include at least the followings (but not limited to):

- Material certificates.
- Thermal Treatments certificates.
- Welding certificates (operators, standard procedures, NDT certificates).
- Coating certificates (Surface treatments, paint thickness, etc.).
- Dimensional and/or alignment checks and relative latest calibration certificates for measuring tools and machines.
- Visual inspections certificates.
- CE certificates.
- Bolt torque certificates.
- RFWs, NCRs.

6.6.8 Assembly procedure

This document shall include all specific assembly, integration, and alignment procedures of particular criticality (especially during telescope integration but not limited to), which shall be delivered to INAF PO to review. These procedures are related to the most delicate equipment (e.g. the Azimuth tracks, Elevation wheels, encoders, and similar devices, critical for the final performance of the LST-S).

The document shall list and describe the steps necessary to assemble, verify proper alignment (including all intermediate checks during the integration phase) and to disassemble the product into its major parts for delivery to site.

The procedure shall list all measuring and alignment equipment, including any special tool, necessary for mechanical and optical alignment of the Product.

6.6.9 Software release version report

The Software Release description is the control document for a unique software version and serves as an index of all applicable documentation. It shall identify the configuration of the software, including the version number. It shall provide a historical reference to all documents under configuration control and indicates the current status of each document.

Additionally, the document shall provide as a minimum:

- Installation procedures.
- Build procedures.
- Configuration Item List.
- Summary of the Acceptance Test Reports.
- List of NCRs, CREs, RFW and RFDs.
- Open works, known issues and limitations.

6.6.10 Test and inspection procedure

The Test and Inspection Procedure shall describe in detail all the necessary operations to perform verification by Test and Inspection outlined inside the Inspection and Test Plan (see section 6.6.3). The Test and Inspection Procedure shall contain the following information, as a minimum:

- Reference to Test and Inspection Plan unique identification code and title.
- Reference to the requirements covered.
- Applicable and reference documents
- Test and Inspection Conditions to correctly perform the Test or Inspection (e.g. special environmental conditions, dedicated tools, calibration requirements, etc.).
- Test and Inspection Procedure description to be executed to grant the verification. For each step, the pass/fail criteria (if any) shall be stated explicitly.
- Test and Inspection Results Presentation description to process the raw data for the final report where applicable.

6.6.11 Test and inspection report

The test and inspection report shall summarize and present the results and findings of the procedures outlined in section 6.6.10, including the following information, as a minimum:

- Test and inspection plan unique label and title.
- Test and inspection conditions (e.g. place, environmental conditions, dedicated tools, calibration certificates, etc.).

- Test/Inspection results processed in such a way that they will be directly comparable with the verification items verified.
- A comparative table shall resume the actuals versus the nominal ones required.
- In case of non compliances, the reference to the related NCRs shall be provided.
- Personnel involved for execution and approval from both parties.
- Appendix: list of attachments of raw data (if applicable).

6.7 PRODUCT SUPPORTING DOCUMENTATION

6.7.1 User manuals

The User Manuals shall describe in detail all the procedures needed to operate correctly and safely the Product. It shall contain, as a minimum:

- A description of the start-up and shut-down procedures.
- A description of all the procedures to operate the system and sub-systems.
- A description of all the operational errors messages for the control units and their solution action.
- A description of all the safety procedures to operate the system and sub-systems.
- A list of all the operational boundaries.
- A list of the emergency cases, which can occur during operations and the associated emergency procedures.
- The reference to any other procedure needed for safe and correct operation troubleshooting and actions to be performed by the operator upon error conditions.
- The operations manuals of the Control System to provide the steps for executing the software, the expected output, and the measures to be taken if error messages appear. Furthermore, it shall also describe, as a minimum:
  - Software design overview and architecture.
  - Software installation.
  - Operating modes.
  - User interface.
  - List of commands and parameters.

6.7.2 Maintenance manuals

The Maintenance Manual shall contain the detailed maintenance procedures with drawings.
It shall contain the maintenance requirements and scheduling for all items included in the supplies of the contract.
All the following types of maintenance shall be considered and the related maintenance actions shall be provided in a tabular format reporting:

- Preventive maintenance (routine and running).
- Corrective maintenance (deferred and urgent).
- Predictive maintenance (condition monitoring based).

Each intervention shall be described with the following information, as a minimum:

- Item(s) to be maintained (product tree reference).
- Qualification and quantity of personnel required for the maintenance activity.
- Total time needed to perform the maintenance activity.
- Supporting tools and equipment (including access).
- Step by step procedure, including detection, preparation, location and isolation, disassembly (gaining access), repair or removal, re-assembly, realignment/re-adjustment, etc., checkout (proof of fault elimination).
- Required parts, consumable.
- Safety implications and measures.

– END OF THE DOCUMENT –

CTA+
LARGE SIZED TELESCOPE SOUTH

LSTS-SPE-INAF-0001-01
MOUNT TECHNICAL REQUIREMENTS

	Name	Role (Institute/ Company)	Date	Signature
Prepared by	Massimiliano Mattioli	Management (INAF)	20.11.2023	
Verified by	Andrea Busatta	PM & SE (INAF)	20.11.2023	
Approved by	Angelo Antonelli	PI (INAF)	20.11.2023	

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Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

CHANGE RECORD

Issue	Date	Sections Affected	Modifications	Author
01	20.11.2023	All	First issue	M. Mattioli

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1 INTRODUCTION

The scope of this document is to provide the requirements for the design and construction of the Mount of CTA South Large Sized Telescope. To accomplish this, the document is divided in a set of Environmental Requirements, Common Requirements (common to multiple sub-systems), and set of requirements dedicated to the Mount. In particular, the sections will be divided with following criteria:

- Introduction
- Definitions
- Environmental requirements
- Common requirements (functional, performance, interface, RAMS)
- Mount
    - Functional
    - Performance
    - RAMS

Definitions, environmental and common requirements are applicable throughout all the telescope sub-units. The Introduction section, besides background and PNRR framework descriptions, report also the list of the Applicable and Reference Documents.

LST-South is funded by European Union – "NextGenerationEU". The points of view and the opinions are only those of the authors and do not necessarily reflect those of European Union or European Commission. Neither European Union nor European Commission can be held liable for those.

1.1 BACKGROUND

The Cherenkov Telescope Array Observatory is an international user facility distributed over four primary sites: Headquarters (Bologna, Italy), Science Data Management Centre (Zeuthen, Germany) and two array sites located in the northern (Observatorio del Roque de los Muchachos (ORM), La Palma, Spain) and southern hemispheres (between Cerro Paranal and Cerro Armazones ESO observatories in Chile).

The Cherenkov Telescope Arrays consists in many tens of telescopes for Gamma Ray observation, divided in three configurations, in order to cover the energy, range from a tens of GeV (Large Sized Telescope, LST), to a tens of TeV (Medium Sized Telescope, MST), and up to 100 TeV (Small Sized Telescope, SST).

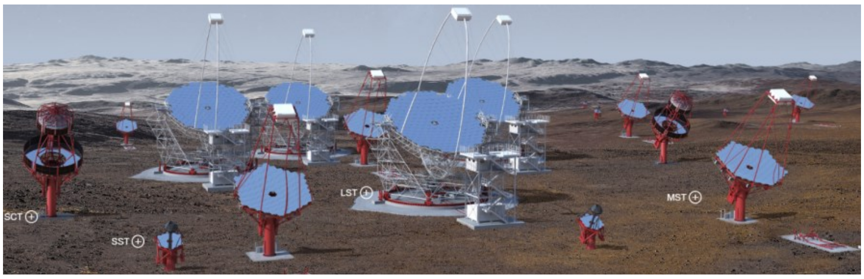

Figure 1.1 Cherenkov Telescope Array artist's impression

Within this framework, INAF is in charge to design, fabricate and test the Large Sized Telescopes located in the southern hemisphere. The location for the LST in the South is approximately located at 24.68°S, 70.32°W at an altitude of ~2150m into the valley between to Paranal and Armazones

Figure 1.2 CTA South (Chile) location aerial view

The LST is an alt-azimuth telescope which have in a primary mirror of 23 m diameter and 28 m focal length; a larger mirror and higher photo detection efficiency allow to detect smaller atmospheric showers. These types of telescopes normally are arranged at the centre of the array to lower the energy threshold and to improve the sensitivity of CTA between 20 and 200 GeV.

Figure 1.3 Artist's impression of Large Sized Telescope into Cherenkov Telescope Array

1.2 THE PNRR NATIONAL PLAN

The National Recovery and Resilience Plan ("Piano Nazionale di Ripresa e Resilienza", PNRR) is part of the Next Generation EU (NGEU) program that the European Union negotiated in response to the pandemic crisis. The total amount of funds envisaged by Italy amounts to several hundreds of billions of euros implemented on specific axes and strategic missions. It is an intervention that aims at repairing the economic and social damage caused by the pandemic crisis, contributing to addressing the structural weaknesses of the Italian economy, and leading the country along a path of ecological and environmental transition and technological advancement.

CTA+ is a program approved by the Italian Ministry to be funded within the PNRR plan. This tender's objective delivers one important task of the project: the telescope mount for the LSTs in the South (CTA+ WP1220).

To reach the program goal, this tender enforces a specific timeline for the execution of the project whose schedule is one of the most demanding achievements since its end is fixed for June 2025. Moreover, a strict monitoring of the activities, costs and deliverables will be executed during the whole project by a supervisory body in order to ensure that the development of the project, in terms of time and costs, is in line with the proposal approved by the Ministry.

1.3 TELESCOPE OVERVIEW AND GLOSSARY

Telescope refers to the whole telescope system, hardware and software. It can be divided in three main subsystems:

- **Telescope structure** (or **Structure**), which is composed by the **Mount** and the **Optics**,
- **Camera** (yellow in Figure 1.4),
- **Telescope Control System (TCS)**, the telescope control software that allows to operate the whole telescope and to interface with ACADA (or OES).

Mount refers to all the telescope systems that allow to support, move, operate, interface, etc. the Optics and the Camera. It can be divided in two main subsystems:

- **Azimuth assembly** (red in Figure 1.4): which is composed by the **Azimuth structure** plus the subsystems located onto it,
- **Elevation assembly** (green in Figure 1.4): which is composed by the **Elevation structure** plus the subsystems located onto it except for the Optics and the Camera.

Mount Structure refers the structural systems only and it is the combination of the Azimuth structure and the Elevation structure.

Axes motion refers to the systems directly responsible for the motion of the telescope. It includes for example Azimuth and Elevation drives, encoders, etc.

Ancillaries refers to the subsystems that support the Axes motion functionalities. It includes for example Azimuth and Elevation cable wraps, locking devices, manual drives, pointing and calibration systems, etc.

Optics refers to the whole optical system. It includes the dish, made of mirror facets (blue in Figure 1.4), and the Active Mirror Control system.

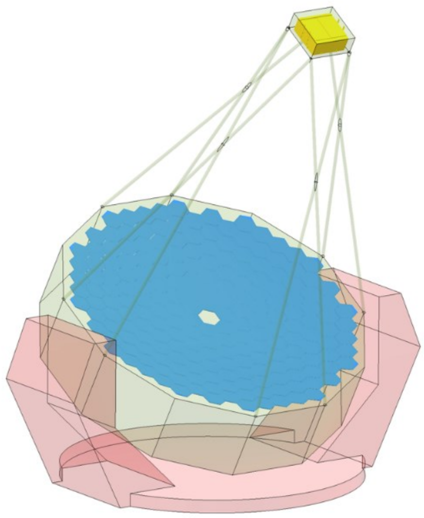

Figure 1.4: telescope sketch for the definition of the glossary used in the document. Yellow: Camera. Red: Azimuth assembly. Green: Elevation assembly. Blue: mirror facets.

1.4 RELATED DOCUMENTS

1.4.1 Applicable documents

AD	Document code	Description
AD01	LSTS-SOW-INAF-0001	Mount Statement of Work
AD02	LSTS-ICD-INAF-0001	Optics to Mount interface control document
AD03	LSTS-ICD-INFN-0001	Camera to Mount interface control document
AD04	LSTS-ICD-INAF-0002	PCS to Mount interface control document
AD05	LSTS-ICD-INAF-0003	TCS to Mount interface control document
AD06	LSTS-ICD-INAF-0004	Array infrastructure interface control document
AD07	CTA-SPE-SEI-400000-0001	CTAO - South Seismic Risk Specification
AD08	CTA-SPE-TEL-000000-0003	Telescope Safety Design Specification
AD09	CTA-PLA-SEI-00000-0001	CTA Product Safety Plan
AD10	CTA-SPE-TEL-000000-0002	Telescope Grounding - Lightning and LEMP Protection

1.4.2 Reference documents

RD	Document code	Description
RD01	CTA-SPE-TEL-000000-0001_2h	Generic Telescope State Machine
RD02	https://opcfoundation.org/	OPC Foundation reference website

1.5 ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Full description
ACADA	Array Control And Data Acquisition system (CTA OES)
AIT	Assembly Integration Test
AMC	Active Mirror Control
CCB	Camera Calibration Box
CDM	Camera Displacement Monitoring
CFD	Computational Fluid Dynamics
CFRP	Carbon Fibres Reinforced Plastic
CI	Configuration Item
CQC	Complete Quadratic Combination
CSS	Camera Support Structure
CTA	Cherenkov Telescope Array
ESS	Energy Storage System
GFRP	Glass Fibres Reinforced Plastic
HW	HardWare
FEA	Finite Element Analysis
FEM	Finite Element Model
FMECA	Failure Mode Effects and Criticality Analysis
FPI	Focal Plane Instrumentation

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Acronym/Abbreviation	Full description
INAF	Istituto Nazionale di AstroFisica
IPS	Integrated Protection System
LRU	Line Replaceable Unit
LST	Large Sized Telescope
LST-S	Large Sized Telescope South
OARL	Optical Axis Reference Laser
OD	Outer Diameter
OES	Observation Execution System, namely ACADA (see ACADA)
OPC-UA	Open Platform Communications, (formerly Object Linking and Embedding for Process Control) - Unified Architecture
PA	Product Assurance
PBS	Product Breakdown Structure
PCS	Pointing and Calibration Systems
PI	Principal Investigator
PM	Project Manager
P&I	Piping and Instrumentation
SAS	Safety & Alarm System
SE	System Engineer
SG	Star Guider
SW	SoftWare
TCS	Telescope Control System

2 DEFINITIONS

The following definitions describe the telescope states, conditions and modes to which the requirements apply (if applicable), and the telescope limit states to which a requirement refers in case an event occurs for a specific configuration of state and condition (when applicable).

2.1 TELESCOPE LIMIT STATES

2.1.1 SL – Serviceability Limit

The structure has not yielded and retained its strength and stiffness. Damage can be repaired in-situ using available spare parts and a normal level of on-site manpower (CTA Global ID CTA-200485). To be more specific refer to following table:

Type of risk	Maximum tolerable consequences
Structural damage	• No structural damage. Telescope structure must behave fully elastic. • Camera structure and its support points shall not suffer permanent deformation • No damage to stow pin, if load event occurred with telescope parked
Optics damage	• No damage to optics due to collision, or support detachment
Camera damage	• No damage to Photomultiplier or electronics and cabling
Operability	• Camera shutter remaining operational after end of the load event, and can be closed remotely • Telescope can be moved on both axes and can be parked with parking script remotely • Brakes can be opened and closed (remotely), stow pins can be inserted (remotely) • Mirror actuators operational and defocusing command can be executed
Breakage	• No system or subsystem breakage. Electrical continuity maintained
Loss of operation	• Maximum loss of operation of one week per telescope due to a) visual inspection and checks, minor realignment *(day-time)*, b) re- establishment of pointing model *(night-time)*
Injuries	• No injury due to parts falling or detachment of optics or part of it, or others

2.1.2 CPL – Collapse Prevention Limit

The structure is heavily damaged, with very limited residual strength and stiffness, yet retains structural integrity and resists collapse. Repairs may require additional resources beyond those usually available on-site (CTA Glossary ID CTA-200486). To be more specific refer to following table:

Type of risk	Maximum tolerable consequences
Catastrophic damage	• No overturn or derailing of the structure, no loss of control position on axes, no damage to foundation, no risk of structural buckling
Structural damage	• No sensible structural damage. Telescope structure must behave largely elastically. Localized area of overstresses beyond yield can be tolerated as long as a) not producing any plastic hinge, and b) can be recovered either by structural realignment or local substitution of flanged beams and parts. • Camera structure and its support points shall not suffer permanent deformation • No damage to stow pin if load event occurred with telescope parked
Optics damage	• Localized and limited damage to optics, not involving support detachment or falls of mirrors. Maximum damage must be recoverable via existing mirror spares at observatory, (typically < 5% optics)
Camera damage	• No damage to Photomultiplier or electronics and cabling
Operability	• Camera shutter remaining operational after end of the load event, and can be closed remotely • Telescope can be moved on both axes and can be parked with parking script remotely • Brakes can be opened and closed (remotely), stow pins can be inserted (remotely) • Mirror actuators operational and defocusing command can be executed • Electrical power to essential services (axes, brakes, stow pins…) must be guaranteed after load event
Breakage	• Minor malfunction of subsystems or parts, as long as spares are available on site. Electrical continuity largely maintained

Type of risk	Maximum tolerable consequences
Loss of operation	• Maximum loss of operation of 6 weeks per telescope, assuming availability of parts on site, and available manpower
Injuries	• No injury due to parts falling or detachment of optics or part of it

2.2 TELESCOPE CONDITIONS

2.2.1 OBC – Observation Conditions

Environmental conditions under which full operation of the CTA System must be possible without incurring damage (CTA Glossary ID CTA-200487).

2.2.2 PPO – Precision Pointing Conditions

Environmental conditions under which it is expected that the optimum pointing precision of the CTA System can be achieved (CTA Glossary ID CTA-200488).

2.2.3 NRM – Normal Conditions (Standard Conditions)

Environmental conditions under which standard operation, engineering and maintenance activities may be undertaken, during day or night (CTA Glossary ID CTA-200491).

2.2.4 TRC – Transition Conditions

Environmental conditions under which environmental parameters may exceed those of the observing state, whilst the system transitions into a safe state (CTA Glossary ID CTA-200489).

2.2.5 SUR – Survival Conditions

Environmental conditions expected to occur with a probability of roughly 2% per annum at each array site. The level of damage incurred under survival conditions must not exceed the serviceability limit state (CTA Glossary ID CTA-200490).

2.2.6 ALC – All Conditions

It refers to all telescope conditions regardless its state.

2.3 TELESCOPE STATES

LST-S Telescope States are depicted in the diagram at Figure 2.1. It represents the State Machine for the structure including all the Machine states and Operational states with sub-states. All Transitions (e.g.: switchOn, switchOff) are managed by the TCS but the sub-states of the Structure state machine are managed internally by the Structure.

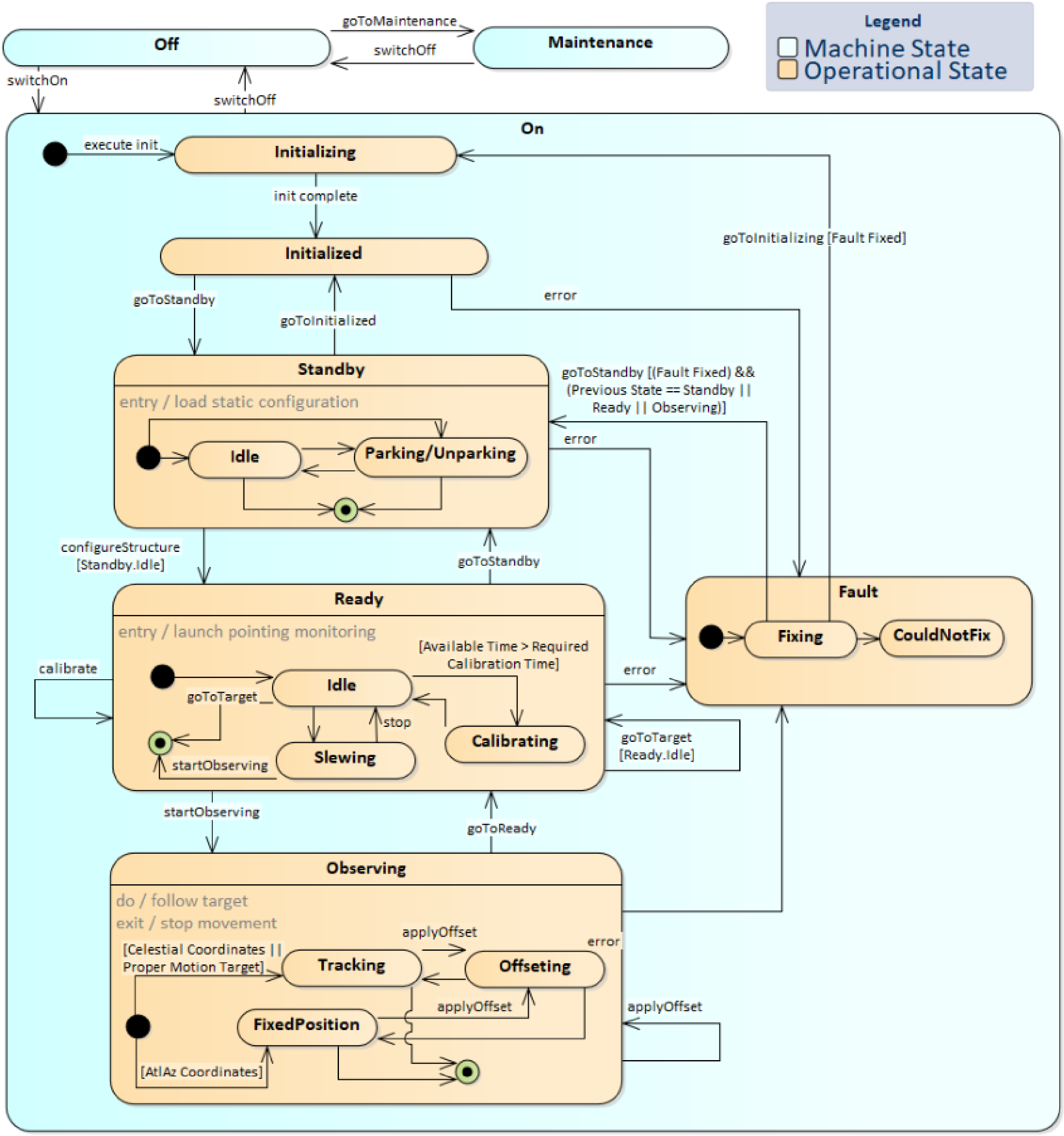

Figure 2.1: State machine of Structure including the states and their sub-states.

2.3.1 Machine States

2.3.1.1 OFS – Off State

The System is entirely without electrical power.

2.3.1.2 ONS – On State

The System is switched on, and available to operate under the operational states described in section 2.3.2.

2.3.1.3 MAS – Maintenance State

The System is in a state designed to perform maintenance activities and is unavailable for scientific operations or any kind of remote control.

Note: monitoring information is still, in general, available for ACADA.

2.3.2 Operational States (ONS sub-states)

2.3.2.1 INS – Initializing State

The System just transitioned to the ON machine state and is initializing all its internal components in order to arrive at the Safe State (also defined as Initialized state).

2.3.2.2 SAF – Safe State (Initialized State)

The System is in a configuration suitable for survival in extreme conditions, minimizing use of power whilst still providing basic status monitoring, and maximizing the instrument lifetime.

Note: It refers to its parking position or special position specifically designed to maintain the telescope safe while not operating.

2.3.2.3 SBS – Standby State

The System is in a state which is still safe with respect to adverse conditions, but has all components activated, with preparations for Observation initiated. Structure has all internal systems on and is unpark.

Sub-states are described as follow:

- **Idle**: already unparked and able to start the transition to “Ready”. Goes to this state if it is already unparked when entering the Standby state.
- **Parking/Unparking**: structure is parking or unparking. When coming from the Initialized state, the Structure starts the unparking procedure, and when done it automatically transition to idle.

2.3.2.4 RDS – Ready State

The System is prepared for a rapid transition to the Observing State. Internal calibration activities may take place.

Sub-states are described as follow:

- **Idle**: Able to go to the Observing state.
- **Calibrating**: Internal telescope calibrations such as when initial mirror alignment for the night happens. Structure cannot be tracking

- **Slewing**: Going to another pointing position. Goes to Ready.Idle, Observing. FixedPosition, or to Observing. Tracking automatically when done, the latter case being when the telescope is instructed to start tracking an Object in the sky upon arrival. Can be cancelled, in that case it goes to the idle sub-state.

2.3.2.5 OBS – Observing State

The System is in a state associated with observatory data taking, with configuration dictated by performance requirements. Data are being taken by Camera, Structure is tracking (or pointing to) the target, calibration activities may take place.

Sub-states are described as follow:

- **Tracking**: Following a position in the sky, or a proper motion target.
- **FixedPosition**: Pointed to a particular fixed position in Alt-Az (e.g. drift scan mode).
- **Offsetting:** Moving to a new position in the same field of view. Goes to the previous sub-state (Tracking or FixedPosition) spontaneously when the operation is finished.

2.3.2.6 FLS – Fault State

The System has encountered a serious problem which means it is currently unable to reach one of the standard states or is unable to continue to maintain the current status. For errors that permit to continue the operation of the corresponding state within requirements, the Element should stay in its correct state while such error is solved (the error is to be logged). Whenever the Element enters in the Fault state, an Alarm shall be raised to IPS and/or ACADA depending on the nature of the Alarm (Safety-related alarms are to be managed by IPS, and operations-related by ACADA.). The transition to this state is automatically performed by the system.

Sub-states are described as follow:

- **Fixing**: Structure is trying self-fix the error. After fixing the error, if the Structure was in the Standby, Ready or Observing state it will try to reach the Standby state. In case the Standby state cannot be reached, of for the other states before the faultand depending on the nature of the error, it will go to the Standby state. Otherwise, it goes to the Initializing states. If the cancelTransition command is issued, the autonomous fixing procedure is interrupted, and the Structure will go to the CouldNotFix state.
- **CoundNotFix**: Structure could not self-fix the error and needs human intervention to fix the problems.
  Note: In addition to SwitchOff, other means by manual interventions using the TCS may allow to return the telescope to the Initialized or Standby State directly.

2.3.3 ALS – All States

It generically refers to all the previous states.

2.4 TELESCOPE MODES

2.4.1 LOM – Local Mode

Mode of operation of a field-deployed Controllable System activated and deactivated by a person physically present at the Interface Cabinet associated with the system. Whilst in Local Mode all remote actions that could endanger the safety of a local person are prevented. Local Mode supports engineering and maintenance activities.

2.4.2 REM – Remote Mode

Mode of operation of a Controllable System to allow control by a person not present at the Array Element Location, available when not disabled at the Interface Cabinet. Remote mode supports observatory science operation and system/array-level engineering activities.

2.5 MOUNT LOCAL CONTROL SOFTWARE

The Mount Local Control Software is the local software responsible for operating the Mount. It controls actuators and monitors sensors by interfacing internally the Drive System's PLCs and it provides an interface to the external systems through the TCS.

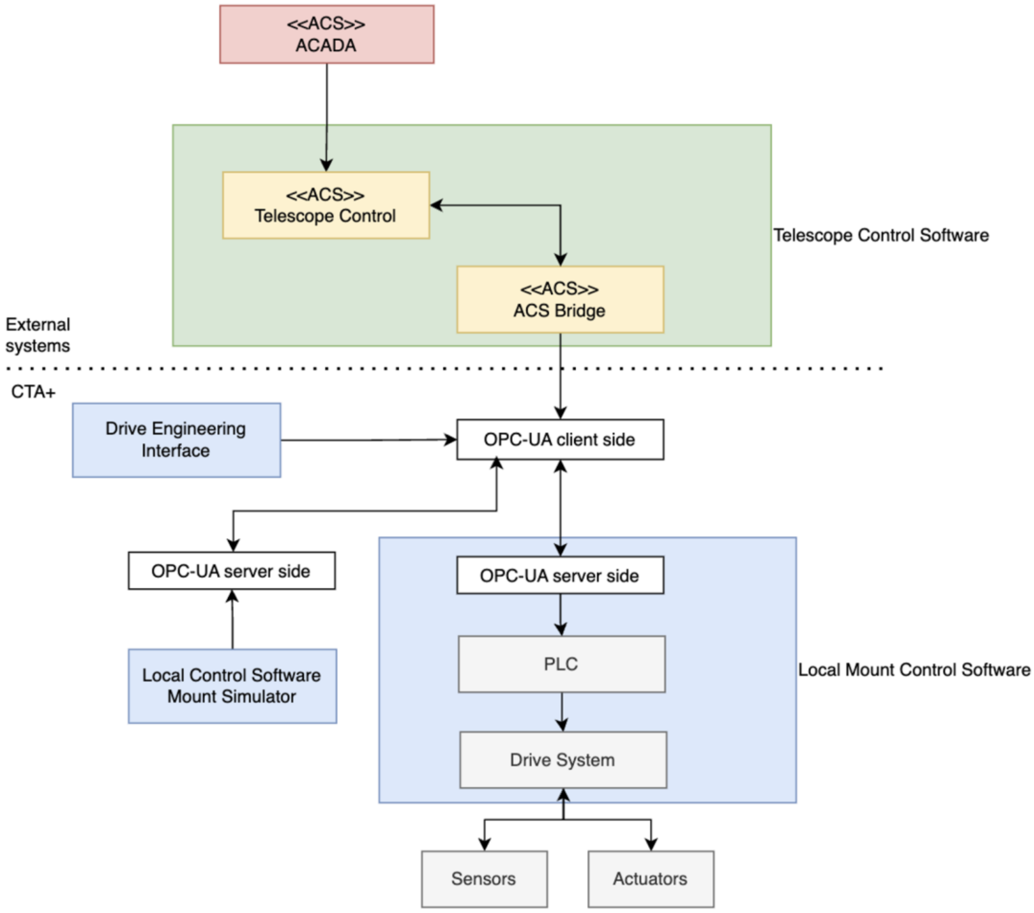

Figure 2.2 LCS top level architecture

A LCS Simulator module and a Drive Engineering Interface module must be provided in order to support the development, integration, testing and engineering operations carried out since from the construction and assembly of the sub-systems.

The communication between all the modules, including the LCS itself, shall be provided over the OPC-UA standard protocol (see RD02).

2.5.1 Top level use cases of the mount LCS

The Mount Local Control Software shall implement the following use cases:

Code	Name	Description
LST-LCS-UC001	Get Status	
LST-LCS-UC002	Initialize	Initialise the drive system and its components for operation
LST-LCS-UC003	Shutdown	Shutdown the drive system and its components
LST-LCS-UC004	Unpark	Un park the telescope
LST-LCS-UC005	Park	Park in the telescope
LST-LCS-UC006	Slew to sky position	Position the telescope for a given pointing
LST-LCS-UC007	Slew to position	Position the telescope for a given position
LST-LCS-UC008	Tracking	Track a direction in the sky
LST-LCS-UC009	Static positioning	Point a fixed telescope position
LST-LCS-UC010	Fast slew to sky position	Fast position of the telescope after an alert for a given pointing
LST-LCS-UC011	Fast slew to position	Fast position of the telescope to a telescope position
LST-LCS-UC012	Stop telescope motion	Stop the telescope motion
LST-LCS-UC013	Circle Tracking	Circular tracking around a direction in the sky
LST-LCS-UC014	Planet Tracking	Track a planet
LST-LCS-UC015	Moon Tracking	Track the moon
LST-LCS-UC016	Emergency stop	Stop the telescope motion using emergency procedure

3 VERIFICATION METHODS

3.1 D – BY REVIEW OF DESIGN

Verification by Review of design shall consist of using approved records or evidence (e.g. design documents and reports, technical descriptions, engineering drawings) that unambiguously show that the requirement is fully satisfied.
The compliance shall be demonstrated by an adequate design, which will be checked by INAF during the design phase of the contract by review of the design documentation.

3.2 A – BY ANALYSIS

Verification by analysis shall consist of performing theoretical or empirical evaluation using techniques agreed with INAF (such as systematic, statistical, and qualitative design analysis, modelling, and computational simulation).
The fulfilment of the specified performance shall be demonstrated by appropriate analysis which will be checked by INAF during the design phase.

3.3 I – BY INSPECTION

Verification by inspection shall consist of visual determination of physical characteristics (such fabrication features, hardware conformance to document drawing or workman requirements, physical conditions, software source code conformance with coding standards).

3.4 T – BY TEST

Verification by test shall consist of measuring product performance and functions under representative conditions (i.e., simulated environments), or under conditions that can be clearly traced to operational ones. The analysis of data derived from testing shall be an integral part of the test and the results included in the test report. When the test objectives include the demonstration of qualitative operational performance, the execution shall be observed, and results recorded.

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4 ENVIRONMENTAL CONDITIONS

4.1 OBSERVATION PRE-CONDITIONS

4.1.1 A-GEN-0450 Rain during observation

Observations must not occur during rain.

Condition: OBS

Verification: requirement not subjected to verification; for information only.

4.1.2 A-GEN-0510 Observation snow load

Observations must not take place when there is snow on the ground.

Condition: OBS

Verification: requirement not subjected to verification; for information only.

4.1.3 A-GEN-0610 Observation ice load

Observations must not take place when ice is present on any surfaces.

Condition: OBS

Verification: requirement not subjected to verification; for information only.

4.2 TEMPERATURE AND RELATIVE HUMDITY

4.2.1 B-ENV-0135 Atmospheric pressure

Performance requirements must be met in the atmospheric pressure range of 770 +/- 50 mbar.

Note: this refers to the site altitude of 2150 m an average temperature of 15 °C.

Condition: ALC

Verification: D, A

4.2.2 B-ENV-0210 Observation temperature

Performance requirements for observations must be met within the ambient temperature range -5°C to 25°C.

Condition: OBC

Verification: D, A

4.2.3 B-ENV-0220 Survival temperature

Damage must not occur due to ambient temperatures within the range -15°C to 35°C when in the Safe State.

Condition: SUR

Verification: D, A

4.2.4 B-ENV-0225 Survival temperature without power

Damage must not occur due to ambient temperatures within the range -10°C to 30°C when no power is available (OFS state).

Condition: SUR

Verification: D, A

4.2.5 B-ENV-0230 Temperature gradient

Performance requirements for observations must be met during air temperature gradients of less than 7.5°C/h.

Condition: OBC

Verification: D, A

4.2.6 B-ENV-0235 Precision pointing temperature gradient

It must be possible to achieve precision pointing under temperature gradients of up to 3°C/h.

Condition: PPO

Verification: D, A

4.2.7 B-ENV-0250 Survival temperature gradient

Damage must not occur due to air temperature gradients of up to 0.5°C/min for 20 minutes when in the Safe State.

Condition: SUR

Verification: D, A

4.2.8 B-ENV-0310 Observation humidity

Performance requirements for observations must be met within the relative humidity range 2% to 90%, provided the condition for operation with un-misted mirrors (see 4.2.10 B-ENV-0330) is met.

Condition: OBC

Verification: D, A

4.2.9 B-ENV-0320 Survival humidity

Damage must not occur due to relative humidity within the range 2% to 100% when in the Safe State or when no power is available.

Condition: SUR

Verification: D, A

4.2.10 B-ENV-0330 Mirror misting

Telescopes must operate with un-misted mirrors when the dew point temperature is at least 2°C lower than the ambient temperature.

Condition: ALC

Verification: requirement not subjected to verification; for information only.

4.3 RAIN, SNOW, ICE, HAIL

4.3.1 B-ENV-0410 Rain in 24 hours

Damage must not occur due to rain precipitation of up to 200mm in 24 hours.

Condition: SUR

Verification: D, A

4.3.2 B-ENV-0420 Rain in 1 hour

Damage must not occur due to rain precipitation of up to 70mm in 1 hour.

Condition: SUR

Verification: D, A

4.3.3 B-ENV-0430 Rain wind speed

Damage beyond the Serviceability Limit State must not occur due to precipitation in the form of rain, snow, or hail for (10-minute average) wind speeds of up to 90km/h.

Condition: SUR

Verification: D, A

4.3.4 B-ENV-0460 Rain during transition

During transitions, damage must not occur due to rainfall of up to 2 mm/h.

Condition: TRC

Verification: D, A

4.3.5 B-ENV-0525 Survival snow load

Damage beyond the Serviceability Limit State must not occur on the CTA-S site whilst in the Safe State due to snow loads of up to 20 kg/m^2.

Condition: SUR

Verification: D, A

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4.3.6 B-ENV-0530 Hailstone damage

Damage must not occur due to the impact of 5 mm diameter hailstones with kinetic energy of 0.2 Joule.

Condition: SUR

Verification: D, A

4.3.7 B-ENV-0625 Survival ice load

Damage beyond the Serviceability Limit State must not occur due to an ice thickness (on all surfaces) of up to 20 mm.

Condition: SUR

Verification: D, A

4.4 WIND

4.4.1 B-ENV-0710 Observation wind speed

Performance requirements for observations must be met under 10 minute average wind speeds of up to 36 km/h.

Condition: OBC

Verification: D, A

4.4.2 B-ENV-0716 Precision pointing wind speed

It must be possible to achieve precision pointing on the CTA-S site under 10 minute average wind speeds of up to 11 km/h.

Condition: PPO

Verification: D, A

4.4.3 B-ENV-0720 Transition wind speed

During transitions, damage must not occur on-site due to 10 minute average wind speeds of up to 50 km/h and damage beyond the Serviceability Limit State must not occur due to 10 minute average wind speeds of up to 60 km/h.

Condition: TRC

Verification: D, A

4.4.4 B-ENV-0740 Survival wind speed

Damage must not occur at the CTA-S site due to 10 minute average wind speeds of up to 80 km/h, and damage beyond the Serviceability Limit State must not occur due to 10 minute average wind speeds of up to 100 km/h when in the Safe State.

Condition: SUR

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Verification: D, A

4.4.5 B-ENV-0745 Survival wind gust

Damage beyond the Serviceability Limit State must not occur on the CTA-S site due to wind gusts (1s) of up to 170 km/h.

Condition: SUR

Verification: D, A

4.5 RADIATION

4.5.1 B-ENV-0810 Solar radiation level

Damage must not occur due to solar radiation of up to 1200 W/m^2 (averaged over 1 hour) at a maximum ambient temperature of 35°C when in the Safe State.

Condition: ALC

Verification: D, T

4.5.2 B-ENV-0820 UV resistance

All components exposed to direct solar radiation must be UV resistant.

Condition: ALC

Verification: D, T

4.5.3 B-ENV-1430 Survival illumination

Damage must not occur due to illumination levels of up to 10^6 photons ns^{-1} cm^{-2} in any state.

Condition: ALC

Verification: D

4.6 DUST AND SAND

4.6.1 B-ENV-0915 Dust and sand

Damage must not occur due to an environment with up to 2.9 x 10^5 particles of ≥5μm size per m^3 of air for 90% of the time at 2m above ground.

Condition: ALC

Verification: D, T

4.7 AGGRESSIVE ATMOSPHERE

4.7.1 B-ENV-1020 Aggressive atmosphere (South)

Damage must not occur on the CTA-S site due to the following Aggressive Atmospheric Concentration ranges when in the Safe State: NO, NO2, SO2<4ppb.

Condition: ALC

Verification: D

4.8 EARTHQUAKE

The equations here below represent the ground acceleration elastic response spectra. The corresponding parameter, as defined by Eurocode 8 are defined in the following subsections for horizontal and vertical direction for both damage limitation and collapse prevention seismic cases.

Here is presented the table with the formulas for the determination of the elastic response spectrum:

Period range	S_e (T)
$0 \le T \le T_B$	$a_g \cdot S \cdot [1+T/T_B \cdot (\eta \cdot c-1)]$
$T_B \le T \le T_C$	$a_g \cdot S \cdot \eta \cdot c$
$T_C \le T \le T_D$	$a_g \cdot S \cdot \eta \cdot c \cdot [T_C/T]$
$T_D \le T \le 4s$	$a_g \cdot S \cdot \eta \cdot c \cdot [T_C \cdot T_D /T^2]$

Where:

- $S_e(T)$ is the elastic acceleration response spectrum in [g]
- T is the vibration period in [s]
- a_g is the peak ground acceleration in [g]
- c is the ratio between the maximum and the peak ground acceleration
- T_B is the lower limit of constant spectral acceleration branch in [s]
- T_C is the upper limit of constant spectral acceleration branch in [s]
- T_D is the value defining the beginning of the constant displacement response range in [s]
- S is the soil factor (amplification factor)
- $\eta = [10/ (5 + \xi)]^{½}$ is the damping correction factor
- ξ is the damping ratio in percent.

Please refer to AD07 for further details.

4.8.1 B-ENV-S-1110 Earthquake damage limitation

Damage beyond the Serviceability Limit State must not occur at the CTA-S site due to the following ground accelerations: Peak horizontal ground acceleration up to 0.25 g, peak vertical ground acceleration up to 0.15 g, with a 10% probability of exceeding these figures within 10 years (reference return period 95 years).

The corresponding parameter for Damage Limitation Requirement (DLR) for earthquake, as defined by Eurocode 8 are defined as per following table and figures for horizontal and vertical directions.

Parameters	a_g [g]	S	T_B [s]	T_C [s]	T_D [s]	c
Horizontal	0.25	1.80	0.10	0.35	2.0	2.0
Vertical	0.15	2.10	0.05	0.30	2.0	2.2

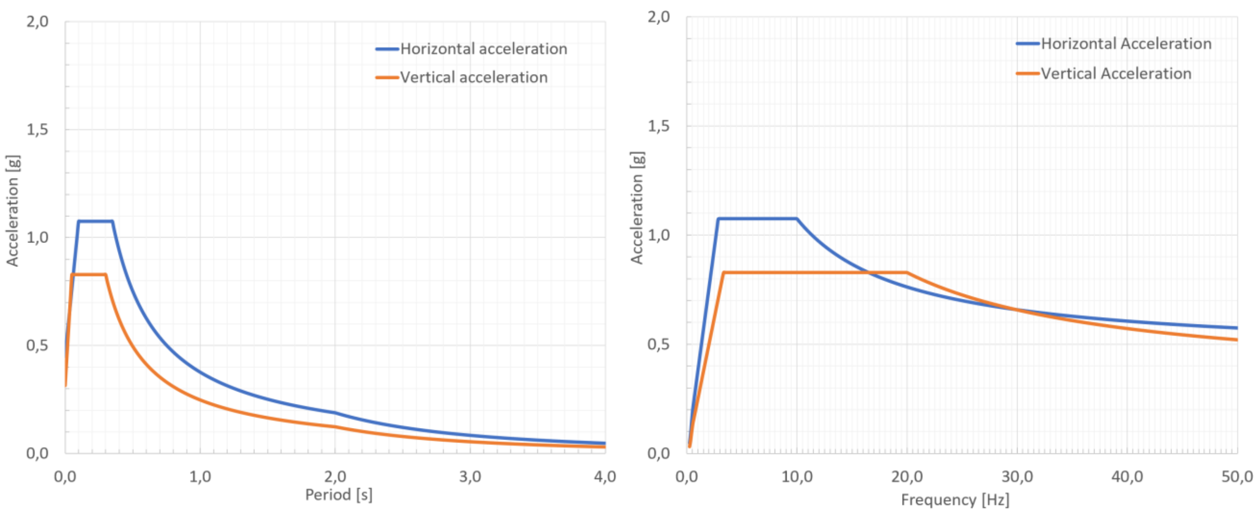


Figure 4.1: Damage Limitation Requirement earthquake spectra expressed as a function of the Period (left) and as a function of the Frequency (right) with damping of 2% for medium soil of CTA Southern site.

Condition: ALC

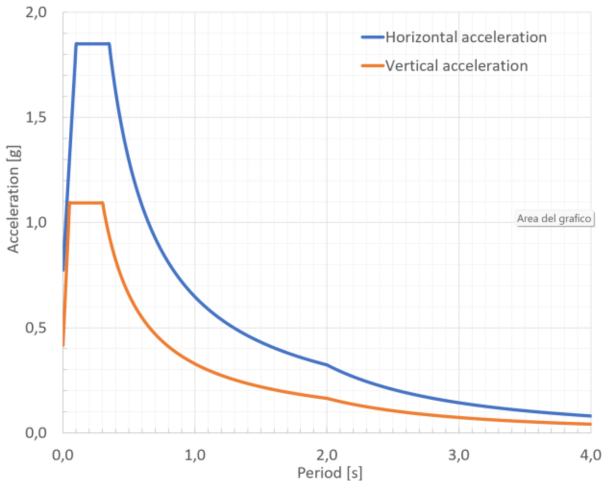
Verification: D, A

4.8.2 B-ENV-S-1120 Earthquake collapse prevention

Damage beyond the Collapse Prevention Limit State must not occur at the CTA-S site due to the following ground accelerations: Peak horizontal ground acceleration up to 0.43 g, peak vertical acceleration up to 0.26 g, with a 10% probability of exceeding these figures within 50 years (reference return period 475 years).

The corresponding parameter for No-Collapse Requirement (NCR) earthquake, as defined by Eurocode 8 are defined as per following table and figures for horizontal and vertical directions.

Parameters	a_g [g]	S	T_B [s]	T_C [s]	T_D [s]	c
Horizontal	0.43	1.80	0.10	0.35	2.0	2.0
Vertical	0.26	1.60	0.05	0.30	2.0	2.2



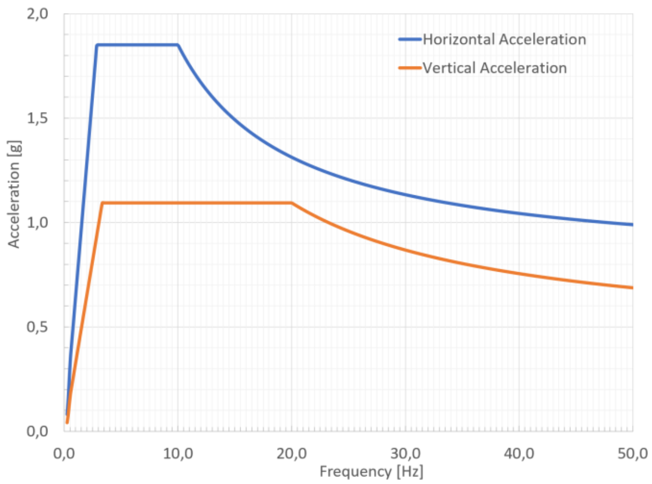


Figure 4.2: No-Collapse Requirement earthquake spectra expressed as a function of the Period (left) and as a function of the Frequency (right) with damping of 2% for medium soil of CTA Southern site.

Condition: ALC

Verification: D, A

4.9 Environmental protection

4.9.1 A-GEN-2185 Environmental protection

Construction, operation and decommissioning of the CTA systems must comply with applicable regulations on the protection of the environment.

Condition: ALC

Verification: D

5 COMMON REQUIREMENTS

5.1 COMMON FUNCTIONAL REQUIREMENTS

5.1.1 Telescope States

5.1.1.1 B-ONSITE-0620 State machine

All Systems must implement a state machine compliant with the diagram shown in Figure 2.1.

Condition: ALC

Verification: D

5.1.1.2 B-ONSITE-0630 State transitions

Transitions between the Safe, Standby, Ready and Observing States must not require any intervention in the field.

Condition: ALC

Verification: D, I

5.1.1.3 B-ONSITE-0710 Remote control

It must be possible to remotely control and monitor the System from the Data Centre using the OES.

Condition: ALC

Verification: D, I

5.1.2 Array clock distribution system

5.1.2.1 B-ACE-0110 Standard timing system

A distributed clock service must be provided to allow synchronization of on-site computing nodes at both array sites via standard protocols.

Condition: ALC

Verification: requirement not subjected to verification; for information only.

5.1.3 Hardware general requirements

5.1.3.1 C-ENV-LST-AUX-S-042001 Outdoor IP Rating

All outdoor connectors and housing (container, cabinet, box) shall be rated IP67.

Condition: ALC

Verification: D, I

5.1.3.2 LSTS-CMN-0001 Connectors IP rating

Connectors and cases installed indoor and/or inside IP67 housing shall be at least IP54.

Condition: ALC

Verification: D, I

5.1.3.3 B-TEL-0060 Electromagnetic compatibility

The Telescope Structure and Camera Unit (as well as its full cooling system) must be electromagnetically compatible, with noise generated by each sub-system having an acceptable level of impact on the performance of the other. The Cherenkov Telescope sub-systems should also be designed to tolerate EM noise associated with local maintenance and engineering activities.

Condition: ALC

Verification: D, A

Note: acceptable level is for example that one compliant with Directive 2014/30/EU.

5.2 COMMON PERFORMANCE REQUIREMENTS

5.2.1 B-LST-0020 Precision post-calibration astrometric accuracy

The Post-Calibration Astrometric Accuracy of an LST Telescope whilst Tracking during Precision Pointing Conditions, must be <14 arcseconds.

Condition: PPO

Verification: A, T

Note: each component of the pointing error budget (e.g.: Post-Calibration performance) will be agreed in coordination with INAF PO.

5.2.2 B-LST-0030 Standard post-calibration astrometric accuracy

The Post-Calibration Astrometric Accuracy of an LST Telescope whilst Tracking must be < 40 arcseconds under standard observing conditions.

Condition: OBC

Verification: A, T

Note: each component of the pointing error budget (e.g.: Post-Calibration performance) will be agreed in coordination with INAF PO.

5.2.3 B-TEL-0040 Online astrometric accuracy

The Online Astrometric Accuracy of the Telescope whilst Tracking must be < 60 arcseconds. Astrometric data delivered to the OES must have a period of validity ending not earlier than 5 seconds before the time of delivery.

Condition: OBC

Verification: A, T

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Note: This is for the purpose of the online analysis and will normally require the application of a telescope pointing model in addition to recorded axis encoder values.

5.2.4 B-ONSITE-0410 Light pollution

Systems must not produce light with an isotropic equivalent flux greater than 3×10^6 photons ns^{-1} at source in the wavelength range 300-550 nm during observations in the absence of specific calibration instructions from OES.

Condition: OBC (considering also the telescopes nearby)

Verification: D, T

5.2.5 LSTS-CMN-0003 Camera allowed acceleration

The foundation and telescope design shall ensure a maximum acceleration (combination of x, y, z components) at the camera lower than 4.5 g under collapse prevention earthquake (see 4.8.2). Consequently, for damage limitation earthquake (see 4.8.1) the maximum allowed acceleration shall be 2.5g.

Condition: ALC

Verification: D, A

5.2.6 LSTS-CMN-0004 Mirror facets allowed acceleration

The foundation and telescope design shall ensure a maximum acceleration (combination of x, y, z components) at each mirror facet lower than 4.25 g under collapse prevention earthquake (see 4.8.2).

Condition: ALC

Verification: D, A

5.3 INTERFACE REQUIREMENTS

5.3.1 Optics interface

The Mount shall host the Optics and all associated Subsystems as imposed by the Optics ICD (AD02).

Condition: ALC

Verification: D, I

Note: all the requirements included in the above ICD need to be satisfied.

5.3.2 Camera interface

The Mount shall host the Camera and all associated Subsystems as imposed by the Camera ICD (AD03).

Condition: ALC

Verification: D, I

Note: all the requirements included in the above ICD need to be satisfied.

5.3.3 Auxiliary systems interface

The Mount shall host the Auxiliary Systems and all associated Subsystems as imposed by the Auxiliary Systems ICD (AD04).

Condition: ALC

Verification: D, I

Note: all the requirements included in the above ICD need to be satisfied.

5.3.4 Telescope Control System interface

The Mount shall ensure the integration with the Telescope Control System as imposed by the Telescope Control System ICD (AD05).

Condition: ALC

Verification: D, T

Note: all the requirements included in the above ICD need to be satisfied.

5.3.5 Array infrastructure interface

The Mount shall ensure the interface with the on-site infrastructure systems as requested by CTAO (AD06).

Condition: ALC

Verification: D, I

5.4 COMMON RAMS REQUIREMENTS

5.4.1 Reliability requirements

5.4.1.1 A-GEN-2510 System lifetime

The design lifetime of the system as a whole is 30 years, all individual assemblies must meet this requirement unless specified separately.

Condition: ALC

Verification: D, A

5.4.1.2 LSTS-CMN-0005 Telescope average motion per night

The telescope shall be capable to accomplish the following duty cycles per night: 900 deg in Azimuth and 540 deg in Elevation.

Condition: OBC

Verification: D, A

5.4.2 Availability requirements

5.4.2.1 LSTS-CMN-0006 Observable nights

The nights suitable for observation shall be considered at least 90%, during which the telescope shall operate 12 hours per night on average.

Condition: ALC

Verification: D, A

5.4.2.2 C-LST-0200 Telescope availability

The availability of each LST Product during observation time must be >95.0 %.

Condition: ALC

Verification: requirement not subjected to verification; for information only.

Note: this includes the entire telescope equipped with the camera.

5.4.2.3 B-LST-S-0310 Telescope mount and optics availability

The availability of each LST Telescope Mount including the Optics System during potential Observation time must be at least 97.5%.

Condition: ALC

Verification: requirement not subjected to verification; for information only.

5.4.3 Maintainability requirements

5.4.3.1 A-GEN-2100 Maintenance/access points

Provision must be made for access and lifting points for safe assembly, maintenance, and disassembly as an integral part of the design of telescopes.

Condition: NRM

Verification: D, T

5.4.3.2 B-ONSITE-0510 Maintenance plans

Maintenance planning and procedures for covering access to, and repair/replacement of, any LRU must be provided.

Condition: NRM

Verification: D, I

5.4.3.3 B-ONSITE-0520 Spare parts

The level of spare parts needed for long-term System maintenance must be documented.

Condition: NRM

Verification: D, I

5.4.3.4 LSTS-CMN-0007 Included Spare parts

Spare parts shall be provided to cover a period of 10 years.

Condition: NRM

Verification: D, I

5.4.3.5 B-ONSITE-0530 Documentation

Systems must be fully documented in terms of operational use and composition/design.

Condition: ALC

Verification: D, I

5.4.3.6 B-ONSITE-0720 Local control mode

Systems must implement a local control mode for maintenance and diagnostic purposes, during which remote operation of safety-relevant sub-systems is blocked. OES must be informed when the System enters Local Mode.

Condition: NRM

Verification: D, T

Note: systems may only return from Local Control Mode to remote mode via a manual switch located at the telescope.

5.4.3.7 Preventive maintenance allowed time

Preventive maintenance shall be carried out during daytime only, except where it implies a safety issue.

Condition: NRM

Verification: D

Note: for example, a telescope elevation motion is not allowed during daytime to prevent sunlight to reach the mirror segments.

5.4.4 Safety requirements

5.4.4.1 LSTS-CMN-0008 CTAO Telescope safety design specification

Telescope safety design shall be compliant with the principles included in AD08 and AD09.

Condition: ALC

Verification: D, A, I, T

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5.4.4.2 B-TEL-1520 Maximum solar concentration

Telescopes should never concentrate sun light to power densities greater than 5 kW/m^2 when in their parked position. Areas and times at which power densities greater than 2 kW/m^2 occur must be identified and clearly documented by telescope providers.

Condition: ALC

Verification: D, I

Note: although not responsible for the solar concentration analysis, the Contractor shall provide the primary mirror position, with telescope in parking position, to allow INAF PO to carry out the analysis and give the feedback about compliance.

5.4.4.3 B-ONSITE-0110 Power on

When the system is in Remote Mode it must automatically transition from the Off State to the Safe State when power is provided.

Condition: ALC

Verification: D, T

5.4.4.4 LSTS-CMN-0009 Sudden loss of power

In exceptional cases a sudden loss of power to Systems may occur and must not cause any damage.

Condition: ALC

Verification: D, A

5.4.4.5 B-ONSITE-0150 Safe state transition

When in remote mode, Systems may not initiate a transition out of the Safe State into the Standby State unless instructed by the OES.

Condition: ALC

Verification: D, T

5.4.4.6 B-ONSITE-0170 Safety signalling

The System must have all the safety subsystems, signs, and acoustic signalling, needed to prevent human injuries.

Condition: ALC

Verification: D, A, I

5.4.4.7 B-ONSITE-0100 Power control

It must be possible for the System power to be controlled both remotely via the SAS and by a person present at the System location.

Condition: ALC

Verification: D, T

5.4.4.8 B-ONSITE-0200 Safety and alarm system connection

The status of system safety interlocks must be provided to the Safety and Alarm System.

Condition: ALC

Verification: D, T

5.4.4.9 B-ONSITE-0210 Automatic transition

The System must initiate a transition to the Safe State if communication with OES is lost for > 1 minute.

Condition: OBC

Verification: D, T

5.4.4.10 B-ONSITE-0220 Loss of clock connection

When in the Ready or the Observing State, the System must initiate a transition to the Standby State if the connection to the Central Computer Time Synchronisation System is lost for more than >20 minutes.

Condition: ALC

Verification: D, T

5.4.4.11 B-ONSITE-0310 Lightning protection

Systems must be protected with a Class 1 lightning protection system in accordance with the international lightning protection standard IEC 62305-1-4:2010.12 (see AD10).

Condition: ALC

Verification: D, A, I

5.4.4.12 B-ONSITE-0330 Flood protection

Systems must be designed to prevent all effects of water collection caused by surface water runoff.

Condition: ALC

Verification: D, I

5.4.4.13 B-ONSITE-0730 Local errors

If the System encounters an error that impacts on proper function/performance, this must be reported to the OES. If recovery from the error is possible, the OES must be notified again when recovery is complete.

Condition: ALC

Verification: D, T

5.4.4.14 B-ONSITE-0740 Local error recovery

All foreseeable error recovery mechanisms must be attempted automatically. In case recovery fails the System must move automatically to a State that prevents damage to instrumentation.

Condition: ALC

Verification: D, T

5.4.4.15 B-ONSITE-0750 Alarm generation

If an error leads to the situation where recovery is not possible, and a Safe State cannot be reached without human intervention then an Alarm must be raised and the System must enter the Fault State.

Condition: ALC

Verification: D, T

5.4.4.16 B-ONSITE-0700 Automatic alarm recovery

Systems must automatically implement standard recovery procedures in the case of Alarms occurring internally to the System.

Condition: ALC

Verification: D, T

6 MOUNT

6.1 MOUNT FUNCTIONAL REQUIREMENTS

6.1.1 Foundation functional requirements

6.1.1.1 B-TEL-0500 Fixation to foundation

Telescopes must provide sufficient design information and a suitable interface to ensure that the Telescope Structure is sufficiently well anchored to withstand the expected static and dynamic loads in the site environment (see section 4).

Condition: ALC

Verification: D, A, I

6.1.1.2 D-TEL-LST-MECH-STR-082004 Foundation cabling

The foundation shall include pass-through for all telescope cabling, including drive, camera, AMC and calibration devices.

Condition: ALC

Verification: D, I

6.1.1.3 C-ONSITE-LST-MECH-033001 Water drainage

The foundation will include drains to prevent accumulation of water during rain.

Condition: ALC

Verification: D, I

6.1.1.4 C-INFRA-LST-MECH-025001 Earth grounding

The foundation will include earth connections for electrical grounding.

Condition: ALC

Verification: D, A, I

6.1.2 Mount functional and parking requirements

6.1.2.1 LST-MNT-0001 Telescope coordinate systems

The telescope coordinate systems shall be chosen as described below and as depicted in the following figures where the yellow and grey blocks are Azimuth and Elevation structures respectively.

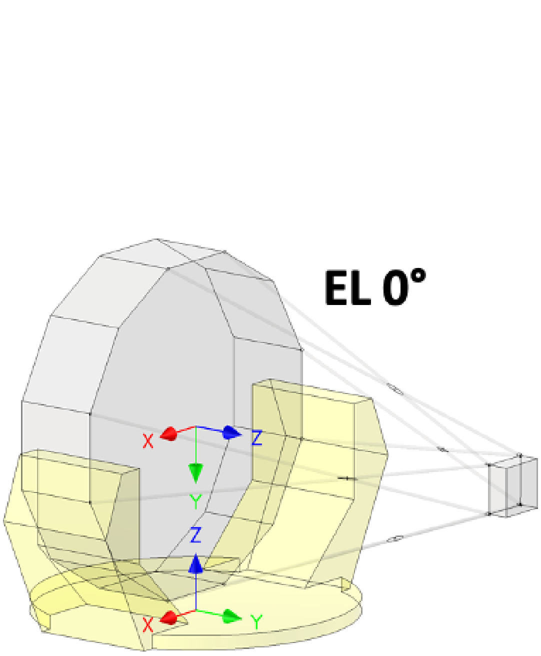

Figure 6.1: telescope coordinate systems

- Azimuth Z-axis is fixed and always points at Zenith.
- Azimuth and Elevation X-axes are always parallel.
- The direction of positive rotations is counter-clockwise (i.e., the Azimuth Z-axis positive rotation turns X-axis towards Y-axis).
- The rotation of the Elevation structure around Elevation X-axis is called “Elevation Angle”.
- The rotation of the Azimuth structure around Azimuth Z-axis is called “Azimuth Angle”.
- Azimuth angle is 0 degrees when Azimuth Y-axis points toward South (TBD).
- Elevation angle is 0 degrees when Elevation Z-axis is parallel and in the same direction of Azimuth Y-axis.

Condition: ALC

Verification: D

6.1.2.2 LSTS-MNT-0045 Azimuth range

The Telescope Structure must have a minimum azimuth range of movement of 510 degrees, with the central 360 degrees used for observations.

Condition: TRC

Verification: D, A, T

Note: it is recommended that a buffer zone of at least 75 degrees at each end should be reserved primarily for ToOs (Target of Opportunities), as indicated by an urgency flag, and engineering purposes. Further note that a telescope coordinate system definition will be provided in a forthcoming document, such that a zero point can also be referred to here.

6.1.2.3 C-LST-S-0351 Elevation range

The Elevation movement range of the telescope shall be from -25 to 160 degrees, with the ranges 20-89.2 degrees usable for standard observations.

Condition: TRC

Verification: D, A, T

Note: the range 89.2-90.8 degrees corresponds to the blind spot. Movement is allowed but tracking of celestial objects during observation is not feasible. The observation within the range 90.8-160 degrees shall be considered as an additional goal.

6.1.2.4 LSTS-MNT-0002 Parked position

Telescope Structures must have a reference “Parked” position, corresponding to the Safe and Standby States, in which the Structure is mechanically locked. Telescope parking position shall be identified in order to minimize the risks for the telescope and human operators deriving from the effect of all the environmental conditions.

Condition: ALC

Verification: D, A, I

Note1: mechanically secured here means prevented from significant motion under the load cases associated with survival conditions.

Note2: parked position shall take into account also the Solar Concentration effect reported in 5.4.4.2.

6.1.2.5 B-TEL-0420 Unparked position

Telescope Structures must have a default position into which they unpark, during transition from Standby to Ready State, and return to prior to parking, at a minimum elevation at which all azimuthal angles are accessible.

Condition: TRC

Verification: D, I

Note1: it can be expected that the Telescope Structure will be in this unparked position during twilight/bright moonlight conditions.

Note2: this is expected to be different from Safe State position if it interferes with free motion for both Telescope axes.

6.1.2.6 LSTS-MNT-0003 Camera maintenance position

Telescope structure shall have a special maintenance position for accessing the camera from its maintenance platform. At the same time, regardless the elevation angle, the structure shall grant to the camera a position for maintenance within the range of 0 (parallel to the ground) to -5 deg with respect to the ground level.

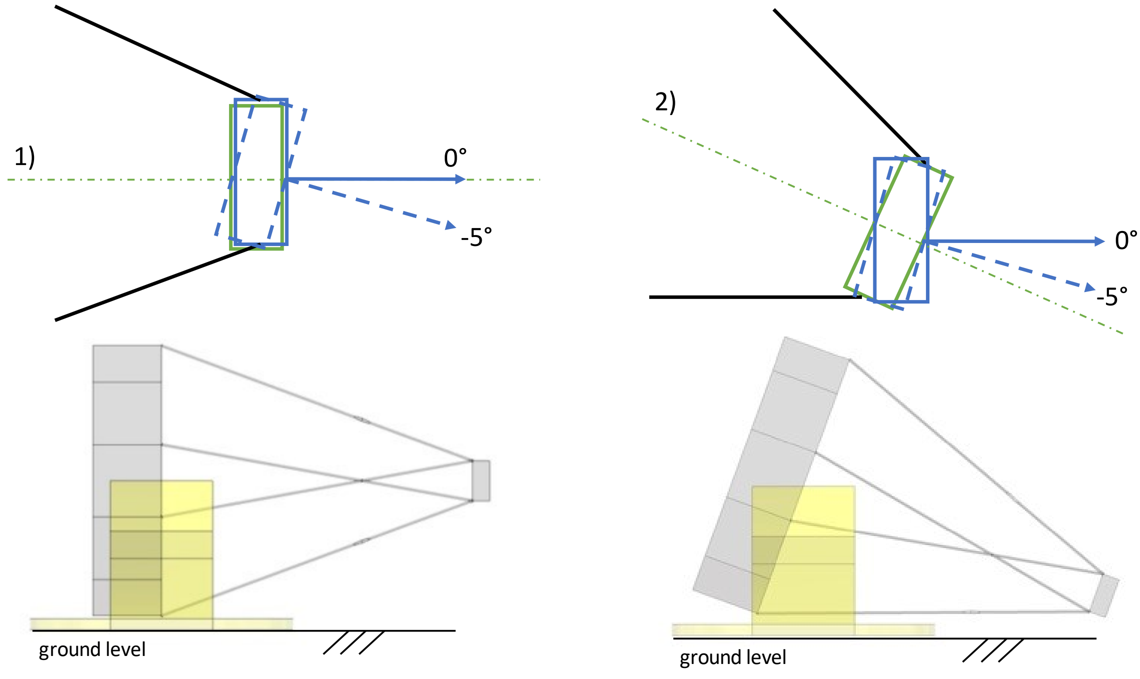

Figure 2: two examples of telescope position vs camera position while in maintenance position.

Condition: NRM

Verification: D, A, T

Note: this position will be approximately at -25 degrees in Elevation if the platform is at the ground level (lowest achievable Elevation angle). This requirement is to be finalized at the delivery of the final ICD.

6.1.2.7 LST-MNT-0004 Camera position repeatability after maintenance

Telescope structure shall guarantee full repeatability (< 0.1 mm and 8 arcsec rms in any direction) of Camera position after maintenance activities.

Condition: NRM

Verification: D, A, T

6.1.2.8 C-LST-MECH-0151 Parking position in Azimuth

The parking position in Azimuth will be the anti-solar pointing position at noon, corresponding to 0 degrees in the northern hemisphere and 180 degrees in the southern hemisphere (in true north-based Azimuth coordinates).

Condition: ALC

Verification: D, T

6.1.2.9 LSTS-MNT-0046 Calibration by external illuminating device

The full field of view must not be obstructed by any telescope infrastructure in an azimuth range of at least 270 degrees for all elevations at or above the horizontal.

Condition: ALC

Verification: D, I

Note: This requirement is motivated by calibration procedures using external ground-based illuminating devices. Once the positions of such devices are fixed the required azimuth range may be reduced.

6.1.2.10 LSTS-MNT-0044 On-axis shadowing

The on-axis shadowing on the primary mirror produced by any part of the telescope (e.g.: camera) shall be less than 36 m^2.

Condition: ALC

Verification: A

6.1.2.11 LSTS-MNT-0005 Assembly concept

The telescope shall be conceived to be assembled, disassembled, and shipped multiple times.

Condition: ALC

Verification: D

6.1.3 Mount motion functional requirements

6.1.3.1 B-TEL-0260 Range optimisation

When repositioning, the Telescope Structure must optimise the telescope motion such that it will not approach the end of the azimuth range (requiring a 360 degrees adjustment) within the next block of observations (the planned duration of the observation will be sent from OES). An exception is for urgent repositioning, where this is not required and the shortest route to the target position should be taken.

Condition: TRC

Verification: D, A, T

6.1.3.2 B-TEL-0215 Fast repositioning

If indicated by the use of an urgency flag, the Telescope Structure must slew to the new position using the most direct route and in the fastest possible time within safety constraints.

Condition: OBC

Verification: D, A, T

Note: range optimisation is not needed for fast repositioning (see B-TEL-0260).

6.1.3.3 D-ONSITE-LST-AUX-019001 Emergency stop

The Drive shall be able to automatically stop the telescope movement without any damage at any time, including the situation the safety end-switches are reached at maximum velocity and especially in elevation.

Condition: TRC

Verification: D, A, T

6.1.3.4 C-ONSITE-LST-AUX-071001 Telescope movement remote control

The telescope movement shall be remotely controllable, allowing locking and unlocking the telescope, moving to a fixed position and track a target within the observation range.

Condition: TRC

Verification: D, A, T

6.1.3.5 C-ONSITE-LST-AUX-072001 Manual control

The drive system shall include a manual control panel that allow locking, unlocking, and moving the telescope in local mode.

Condition: NRM

Verification: D, A, T

Note: no remote commands shall be accepted in local mode (see 5.4.3.6).

6.1.3.6 LSTS-MNT-0047 Automatic response in local mode

All automatic responses of the telescope shall be disabled when local mode is enabled.

Condition: NRM

Verification: D, A, T

Note: this is due to 5.4.3.6.

6.1.3.7 C-LST-MECH-0315 Local mode extend range

Movement range used for maintenance purposes outside the normal observation range and parking position shall only be allowed in local mode.

Condition: NRM

Verification: D, A, T

Note: hazard analysis shall consider this aspect.

6.1.3.8 LSTS-MNT-0052 Pointing calibration

A Pointing Model shall be implemented in order to compensate the Mount repeatable deformations through a pointing calibration procedure.

Condition: OBC

Verification: A, T

Note: Pointing model needs to be tested with temporary astrometric device provided by Contractor.

6.1.4 Mount ancillary requirements

6.1.4.1 LSTS-MNT-0006 Main interface cabinet

The telescope shall have a main interface cabinet which works as interface to the Array infrastructure. It shall include also electrical protections against surges, lightning and short-circuits.

Condition: ALC

Verification: D, I

6.1.4.2 LSTS-MNT-0007 Telescope control container

The telescope shall have a control container which includes the drives and all the equipment needed to control and monitor the telescope. It shall include also electrical protections against surges, lightning and short-circuits.

The Telescope Control Container shall be separated by the Telescope Power Container.

Condition: ALC

Verification: D, I

6.1.4.3 LSTS-MNT-0008 Telescope power container

The telescope shall have a power container which includes the Main Electrical Cabinets of the telescope, which distributes the power from the site grid to the telescope subsystems. It shall include also electrical protections against surges, lightning and short-circuits.

The Telescope Power Container shall be separated by the Telescope Control Container.

Condition: ALC

Verification: D, I

6.1.4.4 LSTS-MNT-0048 Azimuth assembly movement range

The Central pin, pipes and the cables going through it shall not suffer any damage within a movement range of 540 degrees.

Condition: TRC

Verification: D, A, I

6.1.4.5 LSTS-MNT-0049 Central pin cabling

The central pin shall include means (e.g.: cable wrap) to route all the cabling needed for the telescope, including drive, AMC, calibration devices and camera.

Condition: ALC

Verification: D, A, I

6.1.4.6 D-TEL-LST-MECH-STR-S-082005 Mount structure cabling

The Mount structure shall provide means to hold the cables for the camera, AMC, calibration devices and telescope drive.

Condition: ALC

Verification: D, I

6.1.4.7 D-TEL-LST-MECH-STR-082003 Dish cabling

The dish shall provide means to hold the cables for the camera, AMCs and devices installed in the center of the dish.

Condition: ALC

Verification: D, I

6.1.4.8 D-TEL-LST-MECH-STR-082002 CSS cabling

The camera support structure shall include the support mechanics for the camera cabling and cooling pipes.

Condition: ALC

Verification: D, I

6.1.4.9 C-ONSITE-LST-MECH-S-051002 Azimuth structure access

The Azimuth Structure shall include catwalks, stairs, and safety locking points to access the Dish and Azimuth Assembly.

Condition: ALC

Verification: D, I

6.1.4.10 LSTS-MNT-0050 Dish access

The dish shall include catwalks, stairs and safety locking points to access the mirrors and devices installed in its centre.

Condition: ALC

Verification: D, I

6.1.4.11 C-ENV-LST-MECH-S-073001 Uplifting prevention

The Azimuth Assembly shall be equipped with means to avoid the structure experiencing upward loads producing uplifting.

Condition: ALC

Verification: D, A, I

6.1.4.12 LSTS-MNT-0051 Down conductor

The Azimuth and Elevation bearings shall include means to prevent damage due electrical currents (from lightning or short circuits. See AD10).

Condition: ALC

Verification: D, I

6.1.4.13 LSTS-MNT-0009 Structure paint color

The Structure shall be painted with RAL3016 color.

Condition: ALC

Verification: D, I

6.1.5 Power functional requirements

6.1.5.1 C-LST-MECH-0316 Peak power management

The drive system of the telescope will include an energy storage system that provides the peak power needed for fast repositioning.

Condition: NRM

Verification: requirement not subjected to verification; for information only.

Note: although the ESS is not part of the deliverables, the tenderer shall provide an alternative system in order to support the test phase.

6.1.5.2 C-LST-MECH-0304 Backup power

There will be a backup power system for the drive that allows parking and locking the telescope in case of power cut.

Condition: TRC

Verification: requirement not subjected to verification; for information only.

Note: although the backup power system is not part of the deliverables, the tenderer shall provide an alternative system in order to support the test phase.

6.1.6 Mount LCS functional requirements

6.1.6.1 LSTS-MNT-0010 LCS general features

The Mount Local Control Software (LCS) shall control the movement and positioning of the Mount's various components. The LCS shall also include algorithms for calculating the Mount's position, velocity, and acceleration, and for making adjustments to compensate for any sources of error, such as atmospheric refraction or mechanical backlash.

Condition: ALC

Verification: D, A

6.1.6.2 LSTS-MNT-0011 Safety (LCS)

The Mount LCS shall incorporate safety features to prevent telescope damage and human injuries.

Note: for example, the LCS shall enforce the following requirements: 6.1.2.2, 6.1.2.3, 6.1.3.3, etc.

Condition: ALC

Verification: D, T

6.1.6.3 LSTS-MNT-0012 Operating range

The Mount LCS shall prevent the telescope from moving outside of its safe operating range and must issue warning messages and stop the telescope's motion if a safety limit is reached.

Condition: ALC

Verification: D, T

6.1.6.4 LSTS-MNT-0013 Get Status

The Mount LCS shall acquire the telescope status in each state. It includes general information about the telescope like position, velocity, acceleration as well as measurements, readings, warnings and errors from each subsystems controlled and monitored by the LCS.

Condition: ALC

Verification: D, T

6.1.6.5 LSTS-MNT-0014 Initialize

The Mount LCS shall initialise the telescope, i.e., putting the telescope in Initialized state.

Condition: ALC

Verification: D, T

6.1.6.6 LSTS-MNT-0015 Shutdown

The Mount LCS shall shutdown the telescope. The Mount LCS shall ensure that the telescope goes in Park before shutting down the telescope.

Condition: ALC

Verification: D, T

Note: see C-LST-MNT-S0026

6.1.6.7 LSTS-MNT-0016 Unpark

The Mount LCS shall unpark the telescope's drive system, allowing it to move freely. This shall include release of both the Elevation Locking System (ELS) and the Azimuth Locking System (ALS).

Condition: TRC

Verification: D, I, T

Note1: The software should verify that the telescope is in a safe position before unparking the drive system. See Structure machine state (2.3.1).

Note2: The Mount LCS shall set the drive system in standby state.

6.1.6.8 LSTS-MNT-0017 Park

The Mount LCS shall park the telescope. The software should ensure that the telescope is safely parked and secured before parking the drive system.

Condition: ALC

Verification: D, I, T

6.1.6.9 LSTS-MNT-0018 Slew to sky position

The Mount LCS shall slew the telescope in standard velocity to a sky position specified by celestial coordinates R.A./Decl. (given in Epoch J2000). This repositioning can be optionally followed by a tracking. Offset either on celestial coordinates or in telescope attitude can be given.

Condition: TRC, OBC, PPO

Verification: D, I, T

Note1: The Mount LCS should take into account the telescope's current position and orientation before slewing it to the desired position.

Note2: The Mount LCS shall set the drive system in ready state and then in observing state.

6.1.6.10 LSTS-MNT-0019 Slew to position

The Mount LCS shall slew the telescope in standard velocity to a position specified by the telescope local coordinates Alt/Az.

Condition: TRC, OBC, PPO

Verification: D, I, T

Note1: The Mount LCS should take into account the telescope's current position and orientation before slewing it to the desired position.

Note2: The Mount LCS shall set the drive system in ready state and then in observing state.

6.1.6.11 LSTS-MNT-0020 Fast repositioning to sky position

The Mount LCS shall slew the telescope in fast velocity to a sky position specified by celestial coordinates R.A./Decl. (given in Epoch J2000). This repositioning can be optionally followed by a tracking. Offset either on celestial coordinates or in telescope attitude can be given.

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Condition: TRC, OBC, PPO

Verification: D, I, T

Note1: The Mount LCS should take into account the telescope's current position and orientation before fast slewing it to the desired position.

Note2: The Mount LCS shall set the drive system in ready state and then in observing state.

6.1.6.12 LSTS-MNT-0021 Fast repositioning to position

The Mount LCS shall slew the telescope in fast velocity to a position specified by the telescope local coordinates Alt/Az.

Condition: TRC, OBC, PPO

Verification: D, I, T

Note1: The Mount LCS should take into account the telescope's current position and orientation before fast slewing it to the desired position.

Note2: The Mount LCS shall set the drive system in ready state and then in observing state.

6.1.6.13 LSTS-MNT-0022 Tracking

The Mount LCS shall keep the telescope's drive system in sync with a moving celestial object for a specified duration, continuously adjusting the drive system's position and orientation to track the object's movement.

Condition: OBC, PPO

Verification: D, I, T

6.1.6.14 LSTS-MNT-0023 Circle Tracking

The Mount LCS shall keep a circular tracking around a direction in the sky for a specified duration, continuously adjusting the drive system's position and orientation to track the object's movement.

Condition: OBC, PPO

Verification: D, I, T

Note: see 6.1.6.13

6.1.6.15 LSTS-MNT-0024 Track a planet

The Mount LCS shall track a planet in the sky for a specified duration, continuously adjusting the drive system's position and orientation to track the object's movement.

Condition: OBC, PPO

Verification: D, I, T

Note: see 6.1.6.13

6.1.6.16 LSTS-MNT-0025 Track the moon

The Mount LCS shall track the Moon in the sky for a specified duration, continuously adjusting the drive system's position and orientation to track the object's movement.

Condition: OBC, PPO

Verification: D, I, T

Note: see 6.1.6.13

6.1.6.17 LSTS-MNT-0026 Stop telescope motion

The Mount LCS shall stop the telescope's motion in a regular way, ensuring that the telescope is in a safe position before stopping its motion.

Condition: ALC

Verification: D, I, T

6.1.6.18 LSTS-MNT-0027 Emergency stop (LCS)

The Mount LCS shall immediately stop any ongoing motion of the telescope's drive system if an emergency stop is activated and send the telescope in error state.

Condition: ALC

Verification: D, I, T

6.1.6.19 LSTS-MNT-0028 Drive Engineering Interface

The Drive Engineering Interface shall allow the user to control and monitor the telescope in real-time. This functionality shall be offered with a graphical user interface (GUI) that is easy to use and allows the user to input commands, read telescope's parameters (e.g.: current position, velocity, acceleration), display errors and warnings and, more in general, to operate all the use cases described at 2.5.1.

Condition: ALC

Verification: D, I, T

6.1.6.20 LSTS-MNT-0029 Simulator

The Mount LCS shall provide a Mount Simulator tool that emulates the behaviour of the telescope mount system. This simulator will help in testing, debugging, and validating the telescope's control software without requiring access to the actual hardware.

Condition: ALC

Verification: D, I, T

6.1.6.21 LSTS-MNT-0030 OPC-UA standard

The Mount LCS must provide an OPC-UA server interface for command and monitoring.

Condition: ALC

Verification: D, I, T

6.2 MOUNT PERFORMANCE REQUIREMENTS

6.2.1 Foundation performance requirements

6.2.1.1 C-INFRA-LST-MECH-029002 Initial foundation tilting

The maximum tilting of the foundation after the installation will be 0.0095 degrees (2mm differential settlement).

Condition: ALC

Verification: D, I

6.2.1.2 C-INFRA-LST-MECH-029003 Long term tilting

The maximum tilting of the foundation, over long time, will be 0.047 degrees (10mm differential settlement).

Condition: ALC

Verification: D, I

6.2.2 Mount performance and inertial requirements

6.2.2.1 B-TEL-0250 Tracking accuracy

The Telescope must be able to Track any Astrophysical Target for all azimuth angles and for elevation angles 20-89.2 degrees with an instantaneous accuracy of <0.1 degrees on both axes for 99% of the tracking time.

Condition: OBC

Verification: A, T

6.2.2.2 LSTS-MNT-0031 Pointing calibration run frequency

Telescope Structures must not require more than 9 hours per month excluding New Moon night ±3 days for dedicated pointing or PSF calibration observations.

Condition: NRM

Verification: D, A, T

6.2.2.3 C-LST-S-MECH-0158 Telescope mass

The mass of the telescope moving part (i.e. all parts above AZ track) shall be equal to or lower than 140 metric tons.

Condition: ALC

Verification: D, A, I

6.2.2.4 C-LST-S-MECH-0366 Counterweight mass

The telescope elevation structure shall be equipped with counterweights or removable dummies if the distance of its centre of gravity with respect to the elevation axis is greater than 50mm, in all use cases.

Condition: ALC

Verification: D, A, I

6.2.2.5 LSTS-MNT-0053 Azimuth axis inertia

The total telescope inertia to be considered for movements in Azimuth Axis shall not exceed 18600 tons·m².

Condition: ALC

Verification: D, A, T

Note: the worst inertia case is most likely the one with Elevation pointing towards the horizon.

6.2.2.6 LSTS-MNT-0054 Elevation axis inertia

The total telescope inertia to be considered for movements in Elevation Axis shall not exceed 4700 tons·m².

Condition: ALC

Verification: D, A, T

6.2.2.7 LSTS-MNT-0032 Structure minimal natural frequency

The first natural frequency of the moving parts of the telescope above the AZ rail (rail excluded) including all hosted equipment shall be equal or greater than 1.9 Hz.

Condition: ALC

Verification: D, A

6.2.2.8 LSTS-MNT-0055 Azimuth structure deformations

The maximum deformation on any direction for any point of the Azimuth structure relative to the central pin shall be within ±20 mm.

Condition: OBC

Verification: D, A, I

Note: this refers to relative deformations that can happen during observation (wind, temperature changes, elevation angle...).

6.2.2.9 LSTS-MNT-0056 Dish deformations

The maximum deformation on any direction for any point of the dish relative to its centre shall be within ±8 mm.

Condition: OBC

Verification: D, A, I

Note 1: this refers to relative deformations that can happen during observation (wind, temperature changes, elevation angle...).

Note 2: the map of the peak-to-valley displacement of the mirror interface points shall be provided for the ICD (AD02).

6.2.2.10 LSTS-MNT-0057 Camera tilt

The maximum tilt of the camera during observation shall be 0.5 degrees.

Condition: OBC

Verification: D, A, I

6.2.2.11 LSTS-MNT-0033 Static focal plane positioning along optical axis

The centre of the Camera focal plane must be positioned by the Telescope Structure to within ±12.5 mm along optical axis during Observations.

Condition: OBC

Verification: D, A, I

Note: static contribution includes tolerances and gravity (i.e. repeatable contributions).

6.2.2.12 LSTS-MNT-0034 Static focal plane positioning perpendicular to optical axis

The centre of the Camera focal plane must be positioned by the Telescope Structure to within ±20 mm in the direction perpendicular to the optical axis during Observations.

Condition: OBC

Verification: D, A, I

Note: static contribution includes tolerances and gravity (i.e. repeatable contributions).

6.2.2.13 LSTS-MNT-0035 Dynamic focal plane positioning along optical axis

The centre of the Camera focal plane must be positioned by the Telescope Structure to within ±12.5 mm along optical axis during Observations.

Condition: OBC

Verification: D, A, I

Note: dynamic contribution includes all contributions different from static ones such as servo, wind, and thermal effects.

6.2.2.14 LSTS-MNT-0036 Dynamic focal plane positioning perpendicular to optical axis

The centre of the Camera focal plane must be positioned by the Telescope Structure to within ±8 mm in the direction perpendicular to the optical axis during Observations.

Condition: OBC

Verification: D, A, I

Note: dynamic contribution includes all contributions different from static ones such as servo, wind, and thermal effects.

6.2.3 Mount motion performance requirements

6.2.3.1 B-TEL-0710 Structure transition time: Safe to Standby

The Telescope Structure must transition from the Safe State to the Standby State in less than 30 minutes.

Condition: NRM

Verification: D, A, T

6.2.3.2 B-TEL-0720 Structure transition time: Standby to Ready

The Telescope Structure must transition from the Standby State to the Ready State in less than 3 minutes.

Condition: OBC

Verification: D, A, T

6.2.3.3 B-TEL-0730 Structure transition time: Ready to Observe

The Telescope Structure must transition from the Ready State to the Observing State in less than 2 minutes. The opposite transition must be possible on the same timescale.

Condition: OBC

Verification: D, A, T

6.2.3.4 B-TEL-0740 Structure transition time: Return to Safe

The Telescope Structure must transition from the Observing, Ready or Standby State to the Safe State in less than 5 minutes.

Condition: NRM

Verification: D, A, T

6.2.3.5 B-TEL-0750 Structure transition time: Off to Safe

The Telescope Structure must transition from the Off State to the Safe State in less than 4 minutes.

Condition: NRM

Verification: D, A, T

6.2.3.6 LSTS-MNT-0037 Standard repositioning time

The LST Telescope Structure must be able to rotate 180 degrees in Azimuth and 90 degrees in Elevation within 100 seconds at average wind speed of 36 km/h in response to a repositioning request flagged as time critical.

Condition: OBC

Verification: D, A, T

Note: repositioning is considered complete when the Telescope pointing is kept within 0.1 degrees of the requested target.

6.2.3.7 LSTS-MNT-0038 Fast repositioning time

The LST Telescope Structure must be able to rotate 180 degrees in Azimuth and 90 degrees in Elevation within 20 seconds at average wind speed of 36 km/h in response to a repositioning request flagged as time critical.

Condition: OBC

Verification: D, A, T

Note1: repositioning is considered complete when the Telescope pointing is kept within 0.1 degrees of the requested target.

Note2: motor overdrive, beyond nominal torque, can be considered for fast repositioning if it is demonstrated as reliable.

6.2.3.8 B-TEL-0430 Observation pointing safety

In case a Telescope is unable to reach the Safe State/parking position, there must be procedures and plans in place to ensure that damage due to the sun does not occur. It must be possible for two local CTAO personnel to complete a preventative action within 30 minutes at the Telescope, without a connection to the mains power supply.

Condition: ALC

Verification: D, A, T

Note: the applicability of this requirement does not include the possibility for the indicated personnel to move the telescope manually under transition and survival conditions.

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6.2.3.9 C-LST-MECH-S-0322 Emergency stop time

The drive system shall be able to stop the telescope movement when operating in local mode (risk of human injury) in less than 1 second. The velocity of movement can be limited in local mode in order to achieve that.

Condition: NRM

Verification: D, A, T

6.2.4 Power performance details

6.2.4.1 B-LST-0610 Average power consumption during observations

The average power consumption by a single LST Structure during Observations must not exceed 11 kW.

Condition: OBC

Verification: D, A, T

6.2.4.2 B-LST-0620 Peak power consumption during observations

The peak power consumption by a single LST Structure during Observations must not exceed 30 kW.

Condition: OBC

Verification: D, A, T

6.2.4.3 C-LST-AUX-S-062002 Energy Storage System peak power

The ESS shall be able to supply the peak power needed for fast repositioning.

Condition: OBC

Verification: D, A, T

Note: ESS peak power is approximately 350 kW. Although the ESS is not part of the deliverables, the contractor shall provide its specification and an alternative temporary system in order to support the test phase.

6.2.4.4 B-LST-0640 Annual average power consumption in the Safe State

The average power consumption over a full year by a single LST Structure in the Safe State must not exceed 5 kW.

Condition: ALC

Verification: D, A, I

6.2.4.5 B-LST-0630 Peak power consumption in the Safe State

The peak power consumption by a single LST Structure in the Safe State must not exceed 11 kW.

Condition: ALC

Verification: D, A, I

6.3 MOUNT RAMS REQUIREMENTS

6.3.1 Mount reliability

6.3.1.1 B-TEL-0520 Structure lifetime

The structural elements of a Telescope Structure must be designed for an operational Lifetime of 30 years.

Condition: ALC

Verification: D, A

6.3.1.2 B-TEL-0530 Drive lifetime

Telescope drive systems, including servos and gears, must be designed for an operational Lifetime of 15 years.

Condition: ALC

Verification: D, A

6.3.2 Mount availability

6.3.2.1 C-LST-MECH-S-0251 Mount availability

The availability of the LST Mount during observation time must be >99.0 %.

Condition: OBC

Verification: D, A

6.3.3 Mount maintainability

6.3.3.1 LSTS-MNT-0039 Telescope preventive maintenance

The preventive maintenance of a single LST telescope Mount on-site must require on average < 1 person hours / week.

Condition: NRM

Verification: D, A

Note: This is for an overall LST Product preventive maintenance of < 3 person hours / week (from old A-RAMS-0106).

6.3.3.2 LSTS-MNT-0040 Telescope corrective maintenance

The corrective maintenance of a single LST telescope Mount on-site must require on average < 2 person hours / week.

Condition: NRM

Verification: D, A

Note: this is for an overall LST Product corrective maintenance of < 6 person hours / week.

6.3.3.3 LSTS-MNT-0041 Mount condition monitoring

The condition of key telescope Mount elements shall be continuously monitored, to allow early identification of problems and increased availability due to replacement of parts prior to failure, in accordance with the RAMS analysis output.

Condition: ALC

Verification: D, A, I

6.3.3.4 LSTS-MNT-0042 Mount inspection points

All key Telescope Structure elements shall have inspection points to allow the verification of the moving parts.

Condition: ALC

Verification: D, A, I

6.3.4 Mount safety

6.3.4.1 B-ONSITE-0190 Emergency stop

If there is a risk of human injury or death associated with mechanical motions of the System, then a general emergency stop function must be provided which in case of an emergency situation will stop all significant motions of all structural elements with the fastest controllable deceleration, such that no additional risks would be introduced.

Condition: TRC

Verification: D, A, T

6.3.4.2 B-ONSITE-0180 Movement control

Safety mechanisms must exist to ensure that the system can never move in an uncontrolled manner.

Condition: ALC

Verification: D, A, I, T

Note: for example, fail safe brakes and safety switches.

6.3.4.3 B-TEL-0580 Drive control safety

Telescope drive control systems must be provided with safety interlocks that prevent injury to personnel or damage to telescopes that might result from inadvertent operation, human error, or mechanical or control system failure.

Condition: NRM

Verification: D, A, I, T

6.4 MOUNT STANDARDS REQUIREMENTS

6.4.1 LSTS-MNT-0043 Mount applicable standards

The design of the Mount shall make use of adequate set of standards. A table including applicable standards for the Mount design is included here, but it must not be considered complete.

Standard code	Description
	Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on Machinery, and amending Directive 95/16/EC
MIL-HDBK-338B	MILITARY HANDBOOK: ELECTRONIC RELIABILITY DESIGN HANDBOOK
MIL-HDBK-217F	MILITARY HANDBOOK: RELIABILITY PREDICTION OF ELECTRONIC EQUIPMENT
EN Eurocode 0	Basis of Structural Design
EN Eurocode 1	Actions on Structures – All parts
EN Eurocode 2	Design of Concrete Structures – All parts
EN Eurocode 3	Design of Steel Structures – All parts
EN Eurocode 4	Design of Composite Steel and Concrete Structures – All parts
EN Eurocode 8	Design of Structures for Earthquake Resistance – All parts
EN Eurocode 9	Design of Aluminium Structures – All parts
2006/42/CE	Machinery Directive
EN 12100	Safety of Machinery
EN 61010-1	Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements
EN 62061	Safety of machinery, Functional safety of safety-related electrical, electronic, and programmable electronic control systems
EN ISO 13849-1	Safety of machinery -- Safety-related parts of control systems -- Part 1: General principles for design
EN ISO 13850	Safety of Machinery – Emergency Stop – Principles for design
EN 60364 series	Low-voltage electrical installations
EN 60445	Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors, 2010
EN 60664 series	Insulation coordination for equipment within low-voltage systems
MIL-STD-756B	Reliability Modelling and Prediction reference
MIL-STD-882E	System Safety
MIL-STD-1629A	Procedures for performing a Failure Mode, Effects and Criticality Analysis reference
2004/108/EC	EMC Directive
EN 61000 series	Electromagnetic Compatibility (EMC)

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Standard code	Description
Functional Safety and IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
IEC 61131-3	Programmable controllers - Part 3: Programming languages
EN 62305:2011	Lightning protection standard
ISO 14644-1:2015	Cleanrooms and associated controlled environments — Part 1
ECSS-Q-ST-80C Rev.1 (15 February 2017)	Space product assurance – Software product assurance

Condition: ALC

Verification: D, A

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